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U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DISTRIBUTION OF SURFICIAL SEDIMENTS IN OHIO'S NEARSHORE (LAKE ERIE) AS INTERPRETED FROM SIDESCAN SONAR AND 3.5 KHZ SUBBOTTOM DATA

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A cooperative Study of Lake Erie Coastal Erosion by the U.S. Geological Survey, Woods Hole, Massachusetts

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Government or the State of Ohio.

DISTRIBUTION OF SURFICIAL SEDIMENTS IN OHIO'S NEARSHORE (LAKE ERIE) AS INTERPRETED FROM SIDE SCAN SONAR AND 3.5 KHZ SUBBOTTOM DATA

Jonathan A. Fuller

ABSTRACT

Side scan sonar and 3.5 kHz subbottom data were collected along 1,570 km of tracklines from 1993 to 1995. Interpretations of the data were used to map the distribution of nearshore surficial sediments between 500 meters and 3.5 kilometers from shore. Sediment distribution mapping was extended to shore using interpretations of surficial sediments from bathymetric profiles that were run in the 1970's from the shore out to 600 m.

Interpretation of the side scan sonar and 3.5 kHz subbottom records delineated five acoustic backscatter classes that generally correlate with five different sediment types. From the Ohio-Pennsylvania state line to Fairport Harbor and from the west side of the Cleveland harbor complex to Ceylon, rock dominates the lake bed of the inner half of the mapped area and mud or sandy mud dominates the outer half of the mapped area. The inner half of the mapped area from Fairport Harbor to Euclid is dominated by till and lake clays and the offshore half is dominated by sand. Because of the nature of side scan sonar to "see" only the surface, some of the sand and sandy mud areas may be thin veneers over till and lake clays deposits. Data interpretations of the 3.5 kHz reflection record re-enforce the veneer interpretation. From Euclid to the west side of the Cleveland

harbor complex, the bottom is mostly sand and sandy mud exposed in about equal distribution. The inner quarter of the mapped area from Ceylon to Marblehead is dominated by mud, sandy mud, and sand; there are only small outcrops of till and lake clays or rock. Mud predominates in the outer three quarters of the mapped area. The short section of coast from Marblehead to the west side of Catawba Island is a complex of all bottom types with none dominant. The reach from the west side of Catawba Island to Little Cedar Point (near Toledo) is dominated by sandy mud and mud in the outer three quarters of the mapped area and till and lake clays along the inner quarter. Here again, the sediment cover over the till and lake clays is probably a thin lag deposit as suggested by interpretation of the 3.5 kHz data. The nearshore profiles show that narrow deposits of sand exist along most of the shore edge of the mapped area and in some areas, are exposed as beaches.

Some general correlations seem to exist between the nearshore sediment distribution and the bluff recession. Where the bluff is rock recession rates are low and there was little correlation with the nearshore sediments. Where the bluff is till or till related deposits that are erodible, the recession rates seem to be lower where rock dominates the inner half of the mapped area.

INTRODUCTION

Purpose

The area mapped lies between the offshore area mapped by Foster and others (1995) and Fuller and others, (1995), and the shoreline. The mapped area includes data from the area mapped by Carter (1976), Benson (1978), Carter and Guy (1980 and 1983), Guy (1995) which extends out from the shoreline to about 600 m. The information gathered here will assist with studies related to sediment budget, nearshore downcutting and habitat.

Geomorphic Setting

Lake Erie is the shallowest of the Great Lakes and is divided morphologically into three basins. The western basin is the shallowest (average 7 m deep); the largest, the central basin, averages 19 m deep; the eastern basin is the deepest (average 25 m deep). Ohio waters include a large part of the western and central basins (fig. 1). Bluffs along the mainland shore range in height from >20 m to <0.5 m. They are composed of rock (shale or carbonate), glacial deposits (ranging from till to lake clays), and recent deposits that range from mud to nearshore sands including the beach/bar system. Beach widths range from zero to several hundred meters in width. In some areas where rock makes up the shore beaches are absent and water depths at the shoreline can be as much as several meters.

Since the 1940's much of the coast has been modified by shore-protection structures. This process began at the major harbors in the 1800's with construction of harbor jetties and dredging activities. Modification and maintenance of harbor structures continue to the present day. Carter and others (1981) reported that in 1876-1877 there were about 60 structures protecting about 2% of the shore. In the 1940's the numbers had increased to about 1,400 structures with 12% of the shore protected by a dense concentration of structures. The last data reported by Carter and others (1981) were for the mid 1970's when there were about 3,600 structures with 25% of the shore fronted by a dense concentration of structures. Increases in the number of smaller open-coast shore protection structures in the 1950's, 1970's, and 1980's correspond to times of high lake levels and coastal development (Carter, 1976; Benson, 1978; Carter and Guy, 1980, 1983; Carter and others, 1981, 1986).

Geologic Setting

The Ohio portion of Lake Erie lies on the gently eastward dipping flank of the Findlay Arch. Bedrock underlying and exposed in the western basin is Upper Silurian and Devonian carbonates. Bedrock exposed along the central basin bluff in Ohio (east of Sandusky) is Devonian shale.

The Late Wisconsinan glacial and postglacial history of the region has been summarized by Lewis (1969), White (1982), Barnett (1985), Calkin and Feenstra (1985), Coakley and Lewis (1985), Fullerton and others (1991), Szabo (1992) and many others. At least three major ice sheets covered the area. The earliest late-Wisconsinan proglacial lake in the Erie Basin formed about 14,000 yr. BP as the Erie and Huron lobes of the Laurentide ice sheet retreated eastward and northward out of the basin. These proglacial lakes occupied more and more of the Erie Basin as the glacial ice front retreated until about 12,400 yr. BP when the ice left the lake drainage basin.

The postglacial lake stages began with the formation of Early Lake Erie (Calkin and Feenstra, 1985) in the central part of the eastern basin about 12,400 yr. BP (about 35 m below present lake levels). Several curves have been proposed to show how the elevation of the lake rose from Early Lake Erie to modern Lake Erie (Lewis, 1969; Barnett, 1985; Coakley and Lewis, 1985). All these curves show an early rapid rise in elevation of the lake due to rebounding of the isostatically depressed Niagara Escarpment between 12,400 and 10,000 yr. BP. The curves show different possible histories for lake-level recovery within the past 10,000 years, but each includes a rapid rise in water level about 4,000 yr. BP. This rise has been attributed to the return of the upper lakes' drainage to the Erie Basin Coakley and Lewis (1985) and may have resulted in a lake level higher than that of the present lake Barnett (1985).

Previous work

Most of the studies that included nearshore sediment distributions along the Ohio shore of Lake Erie have been have been concerned with the area within about 600 m of shore (U.S. Army Corps of Engineers, 1945, 1950a, 1950b, 1952a, 1952b, 1953a, 1953b, 1953c, 1954, 1961; Carter, 1976; Benson, 1978; Carter and Guy, 1980, 1983). Studies of a more regional scope that also provide information about nearshore sediments include Pincus (1960), Hartley (1961a, 1961b), Sly and Lewis (1972), Sly (1976), and Bolsenga and Herdendorf (1993). Site-specific reports include descriptions of the nearshore sediments in their respective areas (e.g., Herdendorf and Braidech, 1972, Guy, 1983). Herdendorf and others (1978) compiled maps and sediment data summarizing much of the Ohio Geological Survey's (OGS) sample data, including those on which the Hartley (1961a, 1961b) maps were based. Interpretations of recently collected open lake side scan sonar data were plotted by Foster and others (1995) on the Hartley (1961a, 1961b) lake sediment maps.

Nearshore shallow seismic-reflection surveys along the southern shore of Lake Erie (Michigan to New York) were carried out jointly by the U.S. Army Corps of Engineers (USACE) and the OGS (Carter and others, 1982, and Williams and Meisburger, 1982) as part of the ICONS nearshore sand supply studies. In addition a report by Fuller and others (1995) included interpretations of high frequency seismic data from the offshore areas of Ohio as part of a framework study for the USGS cooperative program.

METHODS

Side scan sonar and 3.5 kHz data were collected along 1,570 km of tracklines. There were five tracklines laid out parallel to the shoreline from the Pennsylvania state line to Little Cedar Point near Maumee Bay (maps 1 to 16). These five lines were spaced nominally at 0.6, 1.4, 2.2, 2.5, and 3.2 km from shore. The trackline closest to shore (0.6 km) connected the offshore ends of shore-normal bathymetric profiles, spaced 1.6 km apart, that extend 600 m from shore. The shore-normal profiles are referenced to survey monuments established between 1948 and 1952 as part of a USACE/OGS cooperative coastal erosion study (U.S. Army Corps of Engineers, 1945, 1950a, 1950b, 1952a, 1952b, 1953a, 1953b, 1953c, 1954, 1961). A sixth shore-parallel trackline was subsequently added at a distance of 300 m from shore. This trackline extended from the Ohio-Pennsylvania border to the east end of the Cleveland harbor complex.

Side scan sonar records, supplemented by 3.5 kHz single-channel seismic reflection records, provided the majority of the data for the construction of the maps (1-16).

Nearshore bathymetric profiles run for the OGS county shore erosion reports (Carter, 1976; Benson, 1978; Carter and Guy, 1980, 1983) were used to map from the shoreline out to 600 m offshore. Interpretations from the historical nearshore bathymetric profiles were modified by interpretations of the side scan data provided by the line run 300 m from shore where ever possible. Interpreted sediment contacts from the side scan sonar records and the county erosion report maps were transferred to expanded navigation sheets (nominal scale 1:50,000) to produce the maps in this report.

All of the tracklines except the one 300 meters from shore were run from the Ohio Geological Survey's 15-m research vessel, the R/V GS-1. The 300 m trackline was run from the R/V GS-3, an 8-m vessel designed for shallow-water work (Liebenthal and Fuller, 1996). A cruise summary is included in table 1, the equipment used and typical cruise set-up are summarized in table 2.

RESULTS AND DISCUSSION

Five classes of acoustic backscatter (table 3) were identified and mapped based on the interpretation of the side scan sonar and 3.5 kHz seismic records. The side scan sonar interpretation was cross-checked with published and unpublished descriptions of previously recovered bottom samples and video coverage. This comparison resulted in the development of a correlation between bottom sediment type and acoustic return that is presented in table 3. Examples of these correlations are shown in figures 2 through 6. The mapping presented here agrees well with previous interpretations (for example, Pincus, 1960; Sly 1976; Carter and Guy, 1980, 1983), but adds considerable new detail.

Also incorporated into this nearshore interpretation are data from more detailed studies of bedrock in the nearshore, such as those by Pincus (1960), Carter (1976), Carter and others (1982), Carter and Guy (1983), and the compilation of lake samples by Herdendorf and others (1978), as well as information from Byron Stone, Gerald Shideler (USGS) and Richard Pavey (OGS) (personal communication 1995).

Maps of the surficial deposits from Pennsylvania to Fairport Harbor (maps 1-4) show that there is a very narrow sand beach/bar system. Lakeward of the sand beach/bar system, rock extends offshore to near the 10-m contour. Lakeward of the rock and in the Conneaut and Ashtabula harbor areas, muddy sand and mud are dominant. The dominance of unconsolidated sediment in the harbors appears to be due to a combination of modern fluvial deposits, and littoral drift accumulation due to harbor protection structures.

The reach from Pennsylvania to just east of Fairport Harbor can be generally characterized as high till bluffs exposed to storm winds that have a long fetch from the northeast through the west. The narrow (200 to 300 meters wide) sand beach/bar system has a rough rock rampart, extending about 1.8 km offshore (slope of about 0.48° from the shoreline to the 5-m contour). Rock, resistant to erosion (Carter, 1976, Carter and Guy, 1983), creates a relatively stable (little downcutting) offshore environment. The relatively slow long-term bluff recession rate (0.4 m/yr. for Ashtabula County, Mackey and Guy, 1994) may be due in part to the presence of the relatively stable rough rock rampart in the offshore. Open-lake waves crossing this rampart break multiple times before reaching shore thus dissipating some of their energy over a broad area.

The reach from Fairport Harbor to just east of Moss Point (maps 4 and 6) has a wider sand beach/bar system at the shore than the reach to the east (Pennsylvania-Fairport Harbor). Lakeward of the beach/bar system is a thin band (200 m) of rock and a wider (900 m) band of till and associated material. The outer half of the mapped area is dominated by sand. In this reach the long-term erosion rate increases slightly over that to the east (fig. 7). The 5-m bathymetric contour is slightly closer to shore than along the reach to the east (shore to 5-m slope, 0.57°). These differences (offshore deposits and nearshore slopes) may represent a deepening of the nearshore that allows larger waves to reach the bluff, allowing bluff recession rates to increase.

Offshore of Moss Point (map 6) is a narrow (100 m) beach/bar complex. Nearshore rock (to about 800 m), till and related sediments (from 800 m to 1400 m), give way to muddy sand and sand deposits offshore. The 5-m contour is close to the shore (about 400 m) but the recession rates are slow (fig. 7, Mackey and Guy, 1994). The difference between this area and the rock-dominated nearshore area from Pennsylvania to Fairport Harbor is that here even the bluff is rock; thus, even though more wave energy may reach the bluff the resistant rock results in low bluff recession rates.

The nearshore sediments from Euclid Creek to the west side of the Cleveland harbor complex (maps 6 and 7) are dominated by sand and muddy sand. The eastern half of the reach, which is not protected by the strongly reinforced Cleveland breakwater, has a relatively rapid long term bluff recession rate (0.5 m/yr., Mackey and Guy, 1994) when compared to the Moss Point area (0.1 m/yr.), even though it has had some shore protection since the 1930's (Carter and Guy, 1986). The slope, from the shoreline to the 5-m contour, is the same along this reach as it is in front of Moss Point but the difference is that the bluff is not made of rock and that the nearshore sediments can be mobilized during storms.

From the west side of Cleveland to Cranberry Creek (maps 7-11) the sand beach/bar system varies from 0 to a couple of hundred meters wide. Rock dominates the inner 1.5 km of nearshore deposits with mud extending out to the edge of the mapped areas. The exception to this is between just east of Lorain to Beaver Creek (map 10) where till and related sediments dominate the area beyond the beach/bar system. The average bluff recession rates appear to correlate with bluff composition and the exposure of rock on the lake bottom. Where rock dominates the bluff and the inner nearshore, rates are relatively slower in comparison to those areas where till and unconsolidated sediments are dominant (fig. 7; Mackey and Guy, 1994).

The reach from Cranberry Creek to Sawmill Creek (map 11) has a reasonably well developed sand beach/bar system. The sand deposit is widest where it is trapped on the updrift side of the Huron harbor protection structure. Beaches and bars are absent along a short stretch of shore just west of Huron where rock dominates the nearshore. Lakeward of the beach/bar system (extending out 1 km from shore) the sediments range from till and related deposits at the east end, to sandy mud at the west end of the reach. Generally, mud extends out, from one km from shore, to the edge of the mapped area. The eastern part of this reach, with till offshore of the beach/bar system, has a long-term recession rate of only about 0.1 m/yr. A wide sand beach, trapped in by the Huron jetty, protects the bluff just east of the harbor structure from recession. The area downdrift (west) of the Huron harbor structures, including the area of nearshore rock, has an average recession rate of about 0.2 m/yr. This slightly more rapid bluff recession rate is presumably because it is downdrift from a large structure and because the bluff is generally made up of laminated till and lake clay.

Along most of the reach west of the NASA pump station to Cedar Point (map 11 and 12), a sand beach/bar system fronts a shore of dunes (some protected some not). The beach/bar system varies in width from zero, at the pump station, to more than 200 m, at the Cedar Point jetty. A band of muddy sand extends about 400 meters lakeward from the outer edge of the sand deposit along most of this reach. Lakeward of the muddy sand, mud extends out to the edge of the mapped area. The area just west of the pump station has the highest long-term recession rate (about 3.8 m/yr.) between Conneaut and Sandusky (Mackey and Guy, 1994). Here a low sand barrier was pushed back into a marsh. To the west, recession rates decline to about 0.2 m/yr. where the shore is protected by both riprap and the sand beach/bar system.

The area off Bay Point (map 12) has a sand beach/bar system that is about 800 meters wide. Muddy sand extends from the edge of the sand to the outer edge of the mapped area. This reach has a long fetch from the northeast and has the greatest long-term bluff recession rate, about 5 m/yr., in Ohio's central basin area (fig. 7). However, this rate is not directly comparable to those elsewhere along the shore because it represents retreat of the vegetated upland and movement of a sand spit rather than permanent loss of cohesive bluff material. Along this reach the recession rates and the environments are very similar to those just west of the NASA pump station where the sand barrier was pushed back into a marsh.

From Point Marblehead to Rock Ledge (map 13), all the units (table 3) are present in a complex distribution. The bluff, shore and nearshore areas are dominated by rock except in the East Harbor to West Harbor area where a 400 m wide barrier sand beach/bar system is present. Recession along this whole reach is low (<0.5 m/yr.), even in the area fronted by the beach/bar system. The low rate may be due, in part, to exposures of rock in the bluff and also just offshore in relatively shallow water. In addition, west of East Harbor the fetch lengths for storm waves to build are greatly reduced when compared to those found in the central basin.

From Rock Ledge to Little Cedar Point (maps 13-16) the nearshore is dominated by a 300 m wide sand beach/bar complex. It is widest (about 800 m) just east of Port Clinton and at the west end of Little Cedar Point. Both of these are areas of net accumulation. In many areas a 200 to 800 m wide strip of till and till related deposits lie lakeward of the sand beach/bar complex. Muddy sand makes up the majority of the bottom lakeward of the till extending outward to the edge of the mapped area. Interpretations of the 3.5 kHz records suggest that many of the areas of muddy sand are actually areas with a thin lag on the till surface. Long-term recession rates from Port Clinton to Little Cedar Point are generally 1-2 m/yr. along this low shore dominated by till and till related materials (fig. 7). This rate could have been expected to be even greater given the bluff materials and height, but it may be held down due to a combination of the relatively short fetch and shallow water nature of the whole western basin.

The high long-term recession rate at Little Cedar Point is again not representative of area rates because, as at Bay Point, it represents the movement of a sand spit/barrier beach complex, not the permanent removal of cohesive shore materials. Many other peaks on the recession plot (fig. 7), such as at Mentor, west of the NASA pump station, and Potters Pond, also are associated with the recession of these low sandy barrier beaches.

GENERAL OBSERVATIONS ON NEARSHORE SURFICIAL MATERIAL DISTRIBUTION

Data from the 1970's county shore erosion reports suggest that most of the mainland shoreline is still dominated by a modern sand beach/bar system. This system varies greatly in width but is narrowest along rock bluffs and widest where it is trapped on the updrift side of harbor protection structures. Large sand deposits near the outer edge of the mapped area are limited to between Fairport Harbor and Cleveland. These may be relic sand deposits associated with both the Grand River delta (Carter, 1984) and the Erieau cross-lake moraine (Fuller and others, 1994).

Bedrock outcrops on the bottom, offshore from the sand beach/bar system, from Conneaut to Fairport Harbor, at Moss Point, and from west of Cleveland to Cranberry Creek. These are areas of outcrop of the Devonian Ohio Shale in the bluffs and at, or near, water level. The other outcrop of rock is in the Marblehead to Rock Ledge reach. This reach is associated with the shoreline outcrop of the Silurian and Devonian carbonates. The distribution of outcrops is presumably controlled by the elevation of the rock surface. The rock surface should be somewhat resistant to downcutting, compared to the other surficial deposits, so that once it is exposed on the lake bottom, the potential for continued downcutting is reduced. These outcrop areas are presumably kept clean of modern sedimentation by wave and current action.

Till and till related sediments often outcrop along the lakeward edge of many of the rock outcrops. They also outcrop in a band west of Lorain and offshore of the beach/bar system in the western basin. On shore the common sequence of deposits is till overlying rock. Presumably what is exposed in the offshore is simply the till that has not been stripped off the sloping rock surface, but is kept swept clean of recent sediments by the wave and current action. The outcrop west of Lorain seems to be part of the Pelee-Lorain cross-lake moraine. The outcrops in the western basin are shallow areas swept clean of modern sediments that lie between the modern littoral beach/bar system and the slightly deeper area where modern sedimentation is occurring in the basin.

The distribution of the mud and sandy mud is nearly always at the outer edge of the mapped area. These are interpreted to be the recent sedimentation that is the classic depositional infilling of the lake basin. Sources for these sediments include shore erosion, nearshore downcutting, and input from streams and rivers.

The major harbors are dominated with modern sediments. This is because the harbor protection structures are modifying the littoral drift and deposition is occurring. In addition the fluvial input continues to add recent sediments to the harbor areas as evidenced by the need for continued dredging the navigation channels.

ACKNOWLEDGMENTS

I thank the many people who have provided assistance with the research and preparation of this report. I especially thank Captain Dale Liebenthal of the OGS and Ken Parolski, Dave Nichols, Barry Irwin, Vee Ann Cross, Dave Foster, and Dave Folger of the USGS who were all associated with the field work.

REFERENCES CITED

Barnett, P.J., 1985, Glacial retreat and lake levels, North Central Lake Erie Basin, Ontario: *in* Karrow, P.F., and Calkin, P.E., eds., Quaternary Evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 185-194.

Benson, D. J., 1978, Lake Erie shore erosion and flooding, Lucas County, Ohio: Ohio Division of Geological Survey Report of Investigations 107, 99 p.

Bolsenga, S.J., and Herdendorf, C.E. eds., 1993, Lake Erie and Lake St. Clair Handbook: Detroit, Michigan, Wayne State University Press, 467 p.

Calkin, P.E., Feenstra, B.H, 1985, Evolution of the Erie-basin Great Lakes: *in* Karrow, P.F, and Calkin, P.E., eds., Quaternary Evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 149-170.

Carter, C.H., 1976, Lake Erie shore erosion, Lake County, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey Report of Investigations 99, 105 p.

Carter, C.H., 1984, An Early Lake Erie delta: the Fairport Harbor, Ohio sand deposit: International Association for Great Lakes Research, Abstracts and program of the 27th Conference on Great Lakes Research, p.32.

Carter, C.H., and Guy, D.E., Jr., 1980, Lake Erie shore erosion and flooding, Erie and Sandusky Counties, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey Report of Investigations 115, 129 p.

Carter, C.H., and Guy, D.E., Jr., 1983, Lake Erie shore erosion, Ashtabula County, Ohio: setting, processes, and recession rates from 1876 to 1973: Ohio Division of Geological Survey Report of Investigations 22, 106 p.

Carter, C.H., Benson, D.J., and Guy, D.E., Jr., 1981, Shore protection structures: effects on recession rates and beaches from the 1870's to the 1970's along the Ohio shore of Lake Erie: Environmental Geology, v. 3, p. 353-362.

Carter, C.H., Monroe, C.B., and Guy, D.E., Jr., 1986, Lake Erie shore erosion: the effect of beach width and shore protection structures: Journal of Coastal Research, v. 2, p. 17-23.

Carter, C.H., Williams, S.J., Fuller, J.A., and Meisburger, E.P., 1982, Regional geology of the southern Lake Erie (Ohio) bottom: a seismic reflection and vibracore study: U.S. Army Corps of Engineers, Coastal Engineering Research Center Miscellaneous Report 82-15, 109 p.

Coakley, J.P., and Lewis, C.F.M., 1985, Postglacial lake levels in the Erie Basin, *in* Karrow, P.F., and Calkin, P.E., eds., Quaternary Evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 195-212.

Foster, D.S., Folger, D.W., Circé, R.C., and Fuller, J.A., 1995, Maps and side scan sonar images showing interpretation of acoustic backscatter overlain on historically mapped bottom sediments of the Ohio part of Lake Erie: U.S. Geological Survey Open-File Report 95-252, 14 p., 2 sheets.

Fuller, J.A., Circé, R.C., and Oldale, R.N., 1995, The geologic framework of the Ohio area of Lake Erie: U.S. Geological Survey Open-File Report 95-220, 16 p., 4 figs., 5 pls.

Fullerton, D.S., Cowan, W.R., Sevon, W.D., Goldthwait, R.P., Farrand, W.R, Muller, E.H., Behling, R.E., and Stravers, J.A., 1991, Quaternary geologic map of the Lake Erie 4 x 6 quadrangle, United States and Canada: U.S. Geological Survey Miscellaneous Investigations Map I-1420 (NK-17).

Guy, D.E., Jr., 1983, Origin and evolution of Bay Point sand spit, Lake Erie, Ohio: Bowling Green State University, M.S. thesis (unpub.), 205 p., 5 pls.

Guy, D.E., Jr., 1995, Distribution of nearshore sediment and nearshore bars, Lake County, Ohio (abs.), *in* Folger, D.W. ed., 3rd Annual Lake Erie Coastal Erosion Study Workshop: U.S. Geological Survey Open-File Report 95-224, p. 20.

Hartley, R.P., 1961a, Bottom sediments in the island area of Lake Erie: Ohio Division of Shore Erosion Technical Report 9, 22 p.

Hartley, R.P., 1961b, Bottom sediments of central Lake Erie: Ohio Division of Shore Erosion Technical Report 6, 14 p.

Herdendorf, C.E., and Braidech, L.L., 1972, Physical characteristics of the reef area of western Lake Erie: Ohio Division of Geological Survey Report of Investigations 82, 90 p.

Herdendorf, C.E., and Krieger, K.A., 1989, Overview of Lake Erie and its estuaries within the Great Lakes ecosystem, *in* Krieger, K.A., ed. Lake Erie estuarine systems; issues, resources, status, and management: NOAA Estuary of the Month Seminar Series 14, U.S. Department of Commerce, p. 1-34

Herdendorf, C.E., Gruet, D.B., Slagle, M.A., and Herdendorf, P.B., 1978, Descriptions of sediment samples and cores from the Michigan and Ohio waters of Lake Erie: Center for Lake Erie Area Research, Technical Report # 5, 445 p.

Lewis, C.F.M., 1969, Late Quaternary history of lake levels in the Huron and Erie basins: International Association for Great Lakes Research, Proceedings, 12th Conference, International Association for Great Lakes Research, v. 12, p. 250-270.

Liebenthal, D.L., and Fuller, J.A., 1996, Shallow draft vessel and equipment for collection of nearshore side scan data: (abs.), *in* Folger, D.W. ed., 4th Annual Lake Erie Coastal Erosion Study Workshop: U.S. Geological Survey Open-File Report 96-507, p. 6.

Mackey, S.M., and Guy, D.E., Jr., 1994, Comparison of long- and short-term recession rates along Ohio's central basin shore of Lake Erie (abs.), in Folger, D.W. ed., 2nd Annual Lake Erie Coastal Erosion Study Workshop: U.S. Geological Survey Open-File Report 94-200, p. 19-27.

Pincus, H.J., 1960, Engineering geology of the Ohio shoreline of Lake Erie: Ohio Division of Shore Erosion Technical Report 7, 7 sheets.

Sly, P.G., 1976, Lake Erie and its basin: Journal of the Fisheries Research Board of Canada, v. 33, p. 355-370.

Sly, P.G., and Lewis, C.F.M., 1972, Geology of Lake Erie, in Excursion A43, The Great Lakes of Canada - Quaternary Geology and Limnology: XIV International Geological Congress, Montreal, Quebec, p. 42-50.

Szabo, J.P., 1992, Reevaluation of early Wisconsinan stratigraphy of northern Ohio, *in* Clark, P.U., and Lea, P.D., eds., The last interglacial-glacial transition in North America: Geological Society of America Special Paper 270, p. 99-107.

U.S. Army Corps of Engineers, 1945, Beach erosion study, Ohio shore line of Lake Erie from Ohio-Michigan state line to Marblehead, Ohio: 79th U.S. Congress, 1st Session, House Document 177, 27 p.

U.S. Army Corps of Engineers, 1950a, Cleveland and Lakewood, Ohio, beach erosion control Study: U.S. 81st Congress, 2nd session, House Document 50, 56 p.

U.S. Army Corps of Engineers, 1950b, Appendix IX – Shore of Lake Erie in Lake County, Ohio, beach erosion control study: U.S. 81st Congress, 2nd session, House Document 596, 34 p.

U.S. Army Corps of Engineers, 1952a, Appendixes III, VII, and XII – Ohio shore line of Lake Erie between Fairport and Ashtabula, beach erosion control study: U.S. 82nd Congress, 2nd session, House Document 351, 46 p.

U.S. Army Corps of Engineers, 1952b, Appendixes V and X – Ohio shore line of Lake Erie between Ashtabula and the Pennsylvania state line, beach erosion control study: U.S. 82nd Congress, 2nd session, House Document 350, 46 p.

List of Maps

Table 1. - Summary of shore-parallel trackline cruises.

CRUISE NUM.	M/YR	AREA	R/V	LINE NUM.	NUAT. MI.
LEGS 2-8-93	8/93	Ashtabula	GS-1	36-47	148
LEGS1 8-94	8/94	Sandusky to Toledo	GS-1	1-10	112
LEGS1 9-94	9/94	Cleve. to Sandusky	GS-1	1-15	192
LEGS1 8-95	8/95	Toledo to Conneaut	GS-1	16,26-35 48-54	334
LEGS3 8-95	8/95	Conneaut to Cleveland	GS-3	17-26	60
			total	846 nautical miles	
				1570 kilometers	

Table 2. - Specifications for a typical nearshore seismic cruise[1].

Duration:	seven to nine days
Personnel:	2-3 people
Mobilize & demobilize:	one day
Work days:	63% of available field time (37% down time mostly due to weather)
Work platform:	R/V GS-1, 48-foot, steel, modified trap net design
	RV/GS-3, 25-foot, aluminum, shallow-draft, work boat
Towing speed:	4.8 knots (8.9 km/hr)
Electronic equipment:	3.5kHz seismic system (GS-1 only)
	Geopulse boomer (GS-1 only)
	ITT hydrophone array (GS-1 only)
	Klein sidescan sonar, 100 kHz
	Loran-C navigation with computer interface
	Various recorders, clocks, timers, ect.

[1] Trade names used in this report are used for descriptive purposes only and do not constitute endorsement by the U.S. Geological Survey or the Ohio Geological Survey.

Table 3. - Relation of sediment unit to sidescan-sonar-record backscatter intensity and 3.5kHz seismic-reflection record character.

SEDIMENT	SIDESCAN SONAR RECORD	3.5 kHz REFLECTION RECORD
Mud	Low backscatter, little reflection	Internal reflectors, no water bottom multiple
(with gas)	High backscatter	Strong reflectors - poor penetration, strong water bottom multiples
Muddy sand	Intermediate to strong backscatter, few surface features	Intermediate reflectors, may have internal reflectors
Sand/silt	Intermediate backscatter, complex surface, fairly consistent backscatter	Smooth surface, few to no internal reflectors, some multiples
Till, laminated till, glacial lake clay	Intermediate to high backscatter, strong reflections, complex surface	Many internal reflectors and rough surface, to no internal reflectors and smooth surface, multiples common
Rock	High backscatter, dark complex pattern, bedding planes in shale surface	Sharp hard reflector, rough surface, multiples very common

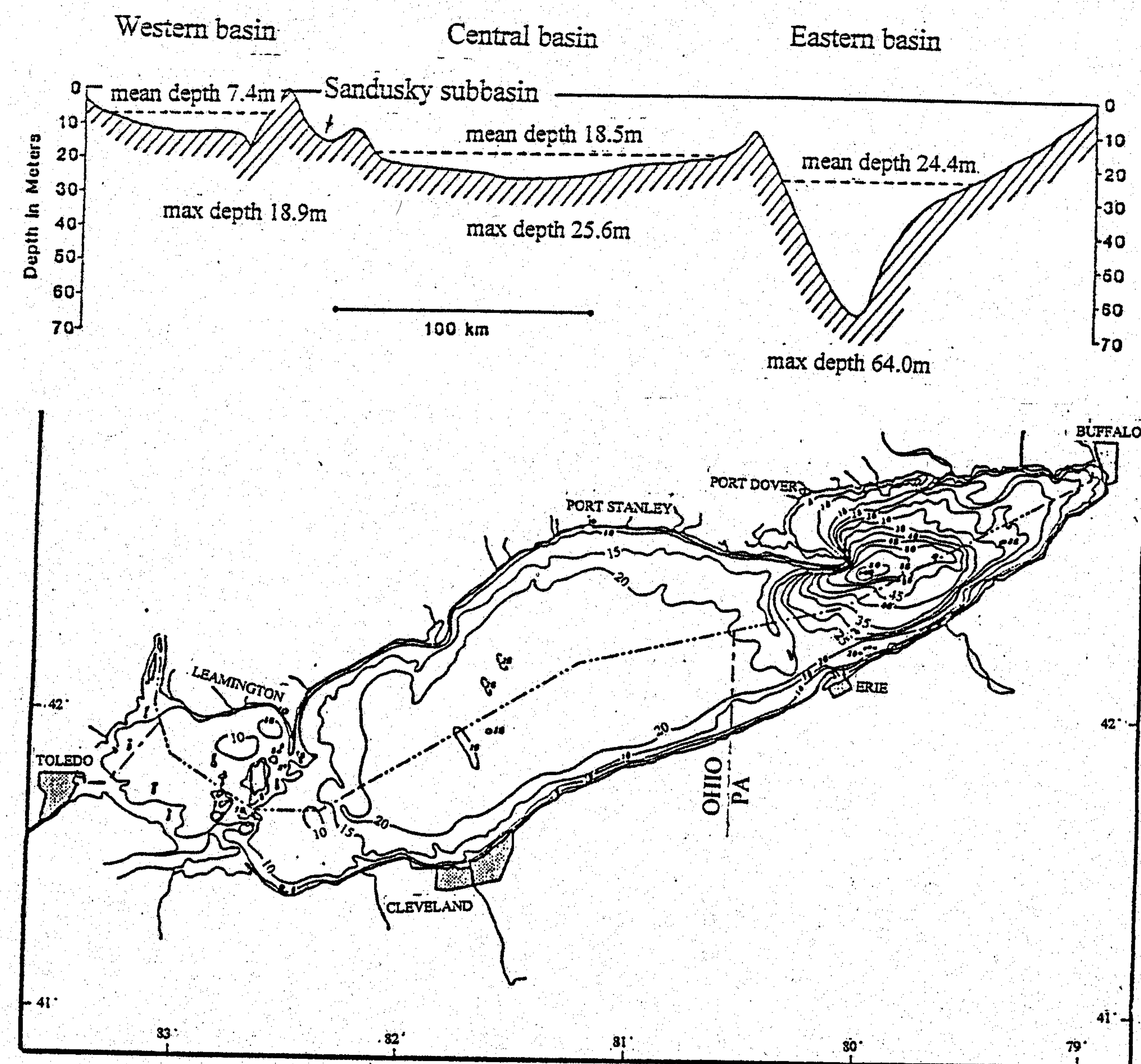


Fig. 1. Generalized bathymetry of Lake Erie showing three basins, in plan and cross-sectional views. Modified from Herdendorf and Krieger, (1989). Contour interval 5 meters.

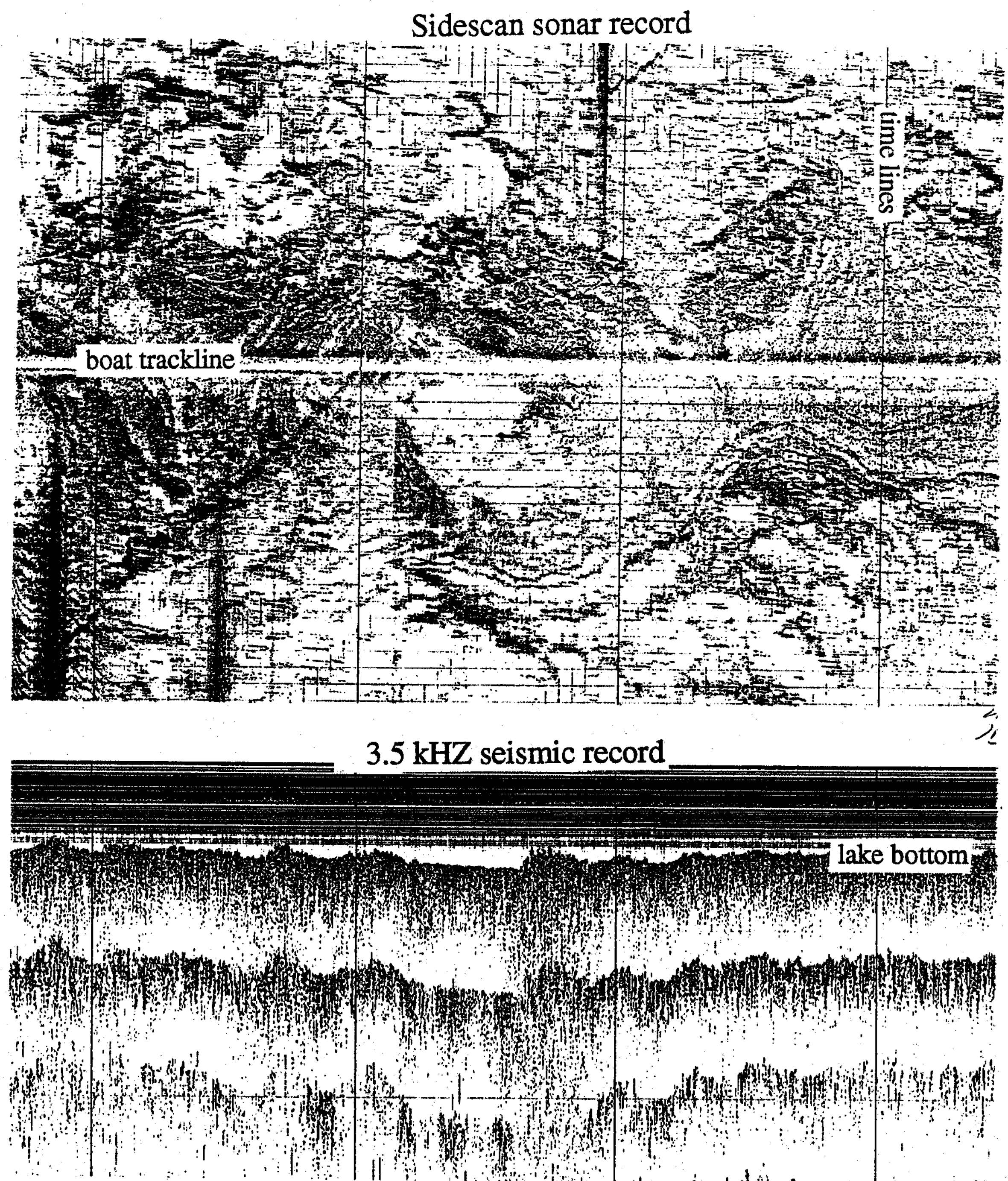


Fig. 2. Rock outcrop as seen on the sidescan sonar (top) and 3.5 kHz seismic-reflection (bottom) records. For interpretation see table 3.

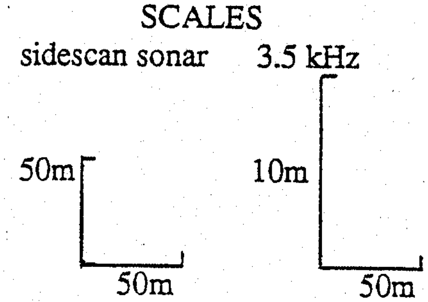
Cruise LEGS 1 9/94, line 9.

Time lines = 1 minute

Sidescan range = 200 meters each side (400m swath)

3.5 kHz range = 40 meters

Assumed sound velocity = 1,500m/sec



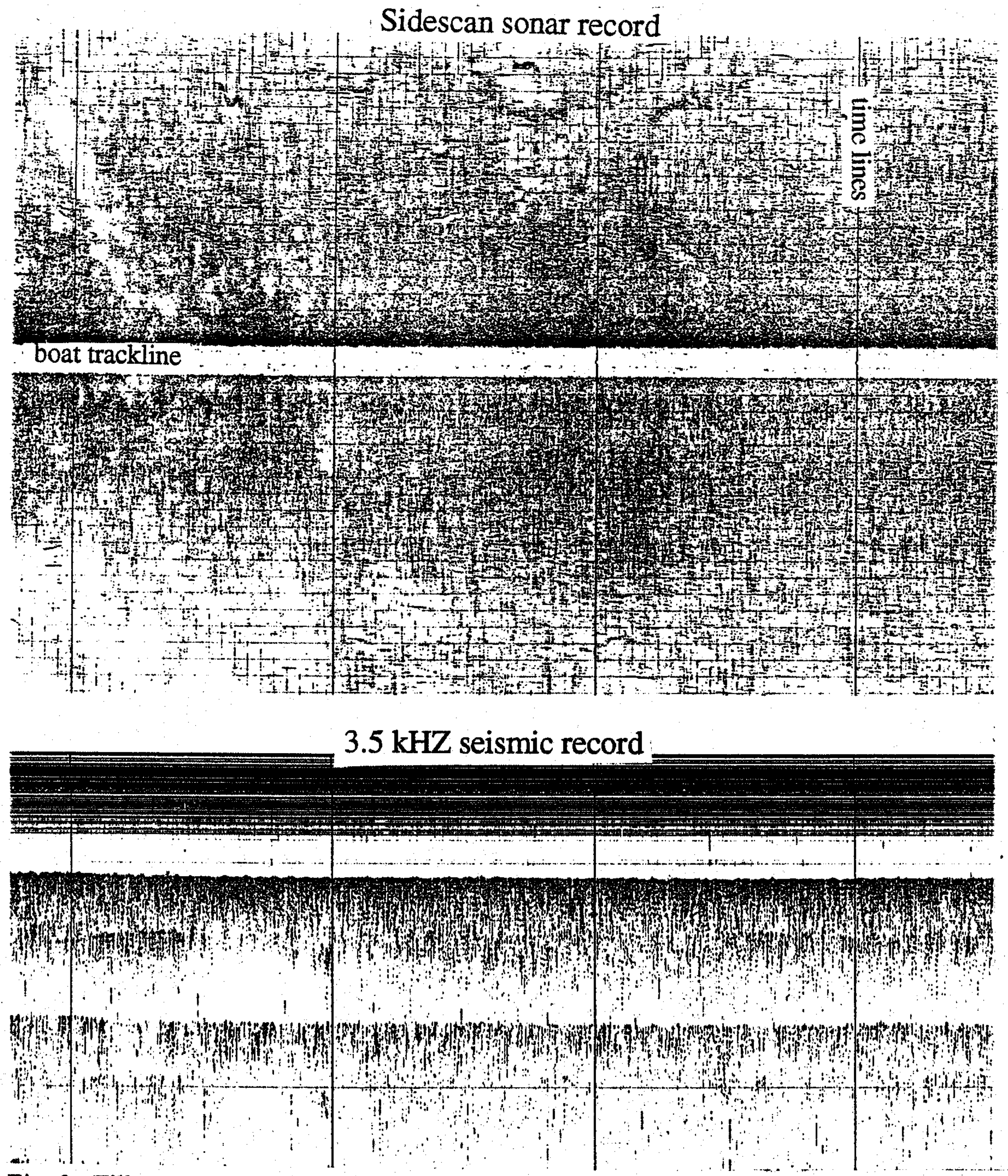
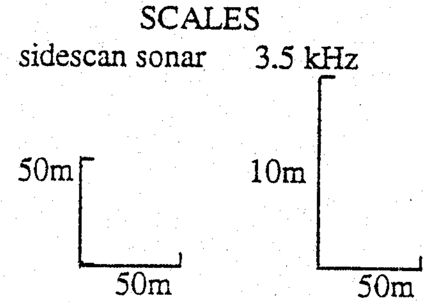


Fig. 3. Till outcrop as seen on the side scan sonar (top) and 3.5 kHz seismic-reflection (bottom) records. For interpretation see table 3.
Cruise LEGS 1 9/94, line 9.

Time lines = 1 minute
Side scan range = 200 meters each side (400m swath)
3.5 kHz range = 40 meters
Assumed sound velocity = 1,500m/sec



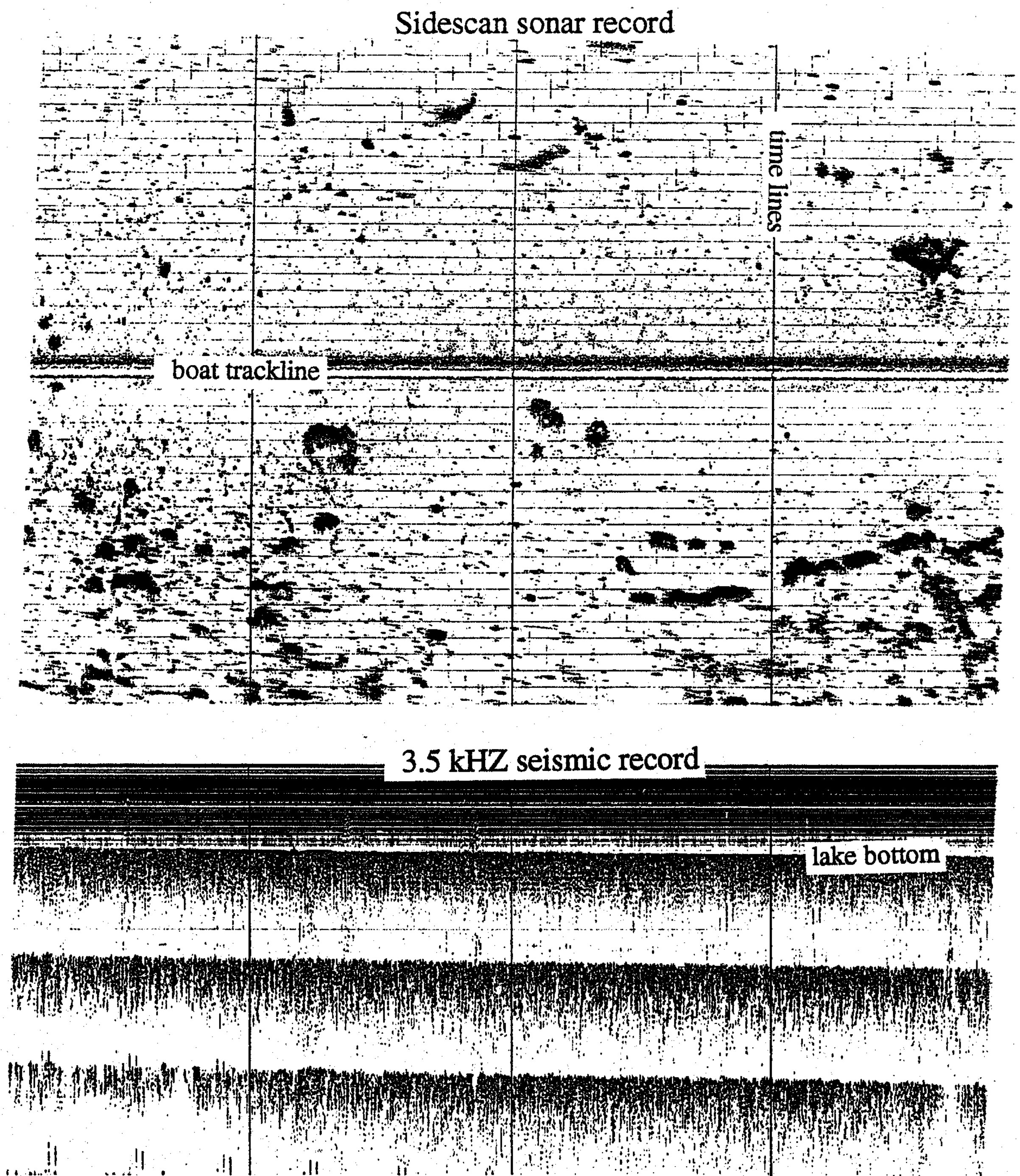
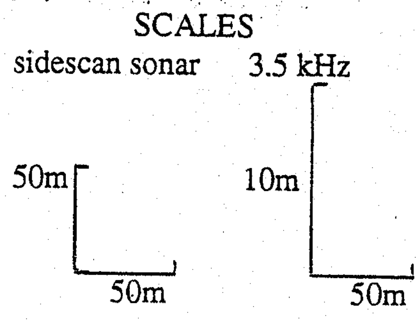


Fig. 4. Sand outcrop as seen on the sidescan sonar (top) and 3.5 kHz seismic-reflection (bottom) records. For interpretation see table 3.
Cruise LEGS 1 9/94, line 9.
Time lines = 1 minute
Sidescan range = 200 meters each side (400m swath)
3.5 kHz range = 40 meters
Assumed sound velocity = 1,500m/sec



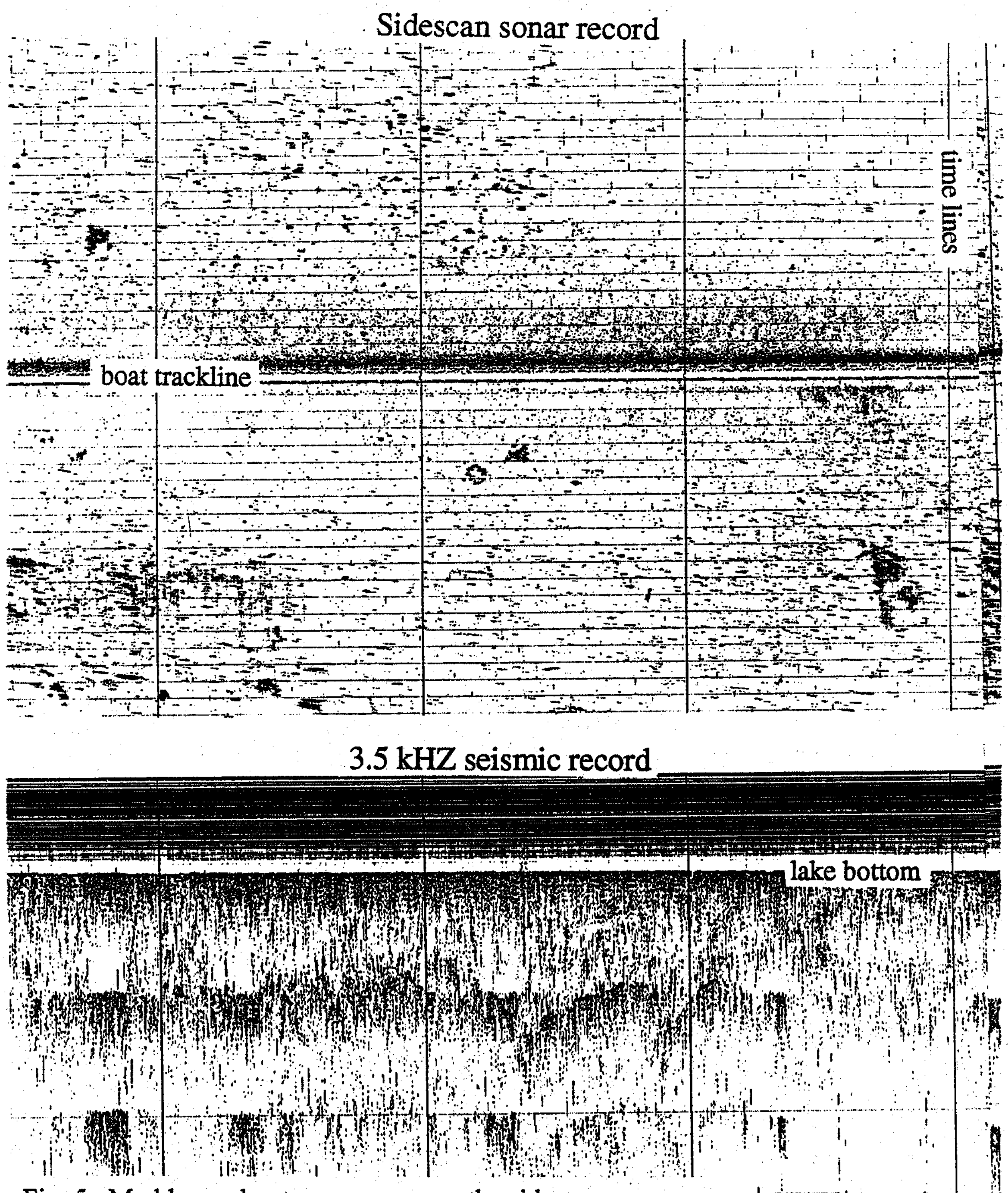


Fig. 5. Muddy sand outcrop as seen on the sidescan sonar (top) and 3.5 kHz seismic-reflection (bottom) records. For interpretation see table 3.

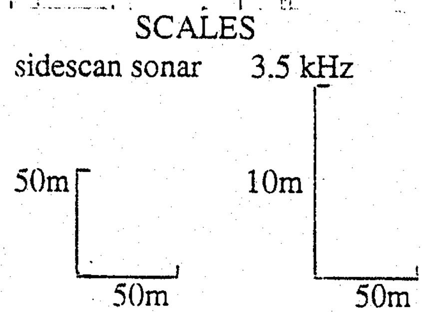
Cruise LEGS 1 9/94, line 9.

Time lines = 1 minute

Sidescan range = 200 meters each side (400m swath)

3.5 kHz range = 40 meters

Assumed sound velocity = 1,500m/sec



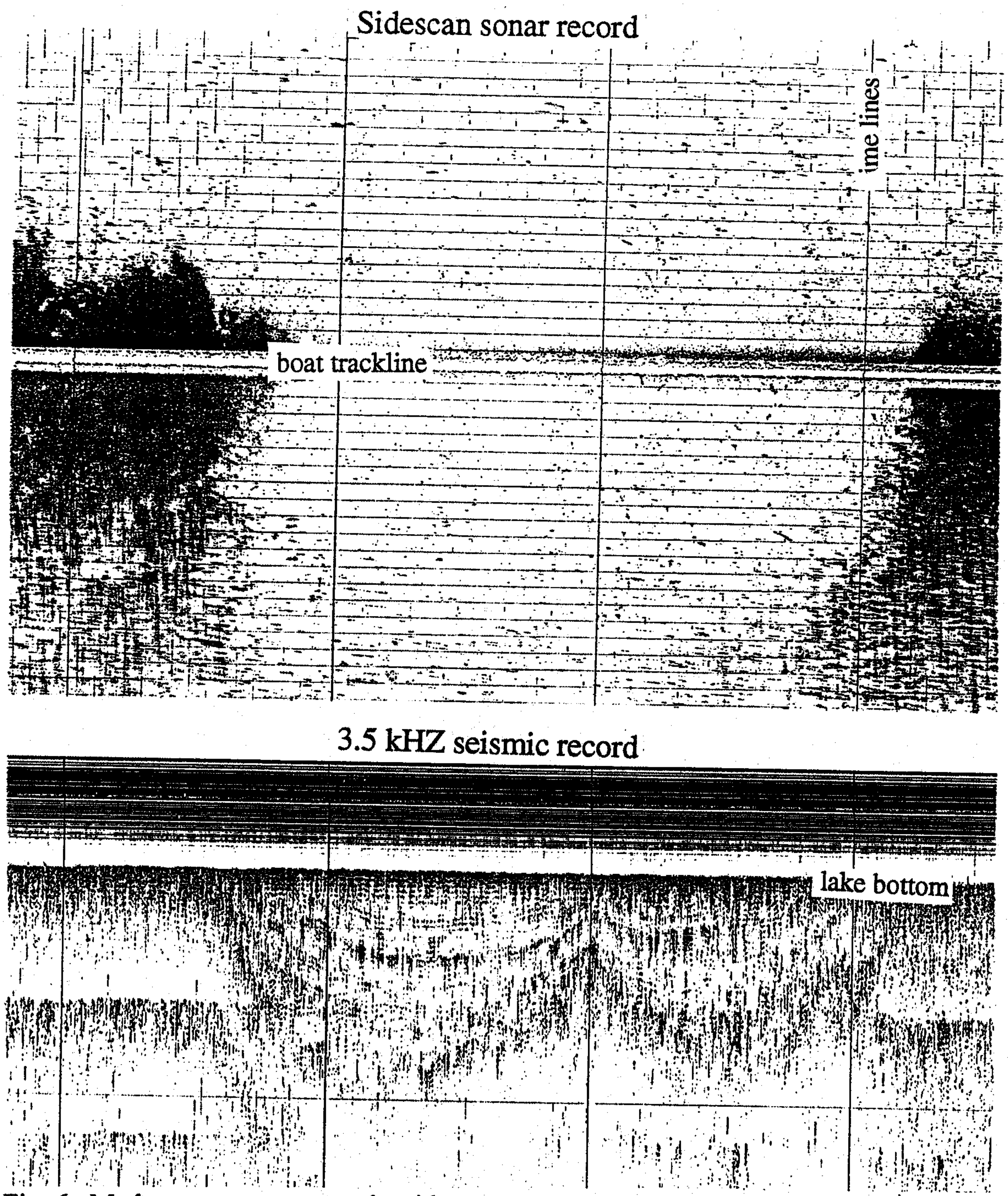


Fig. 6. Mud outcrop as seen on the sidescan sonar (top) and 3.5 kHz seismic-reflection (bottom) records. For interpretation see table 3.

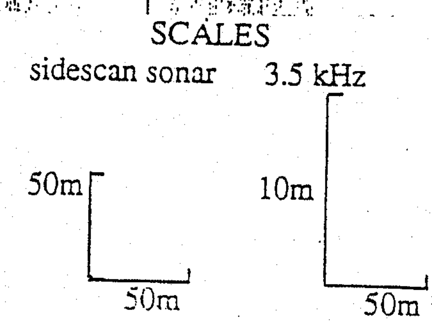
Cruise LEGS 1 9/94, line 9.

Time lines = 1 minute

Sidescan range = 200 meters each side (400m swath)

3.5 kHz range = 40 meters

Assumed sound velocity = 1,500m/sec



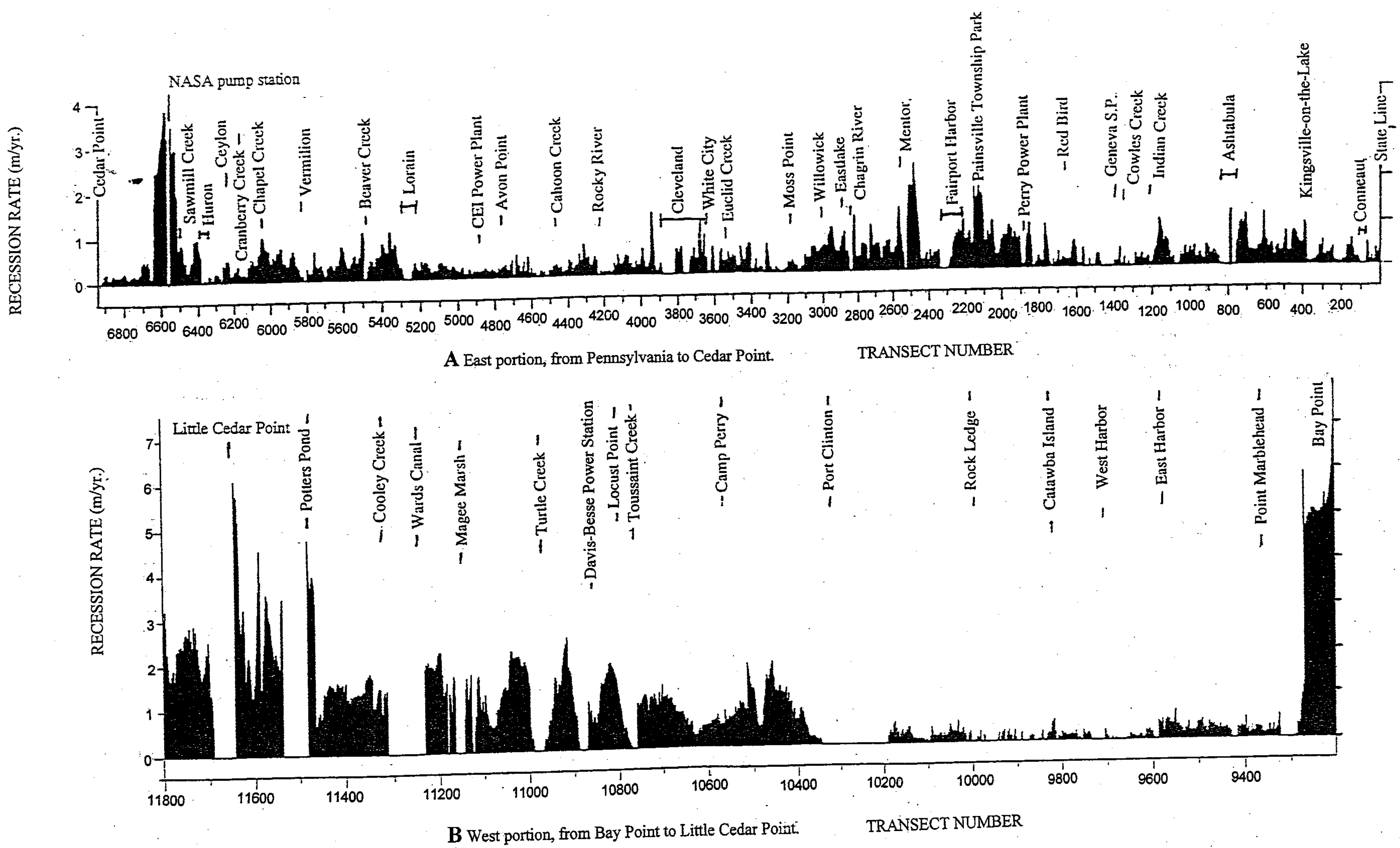
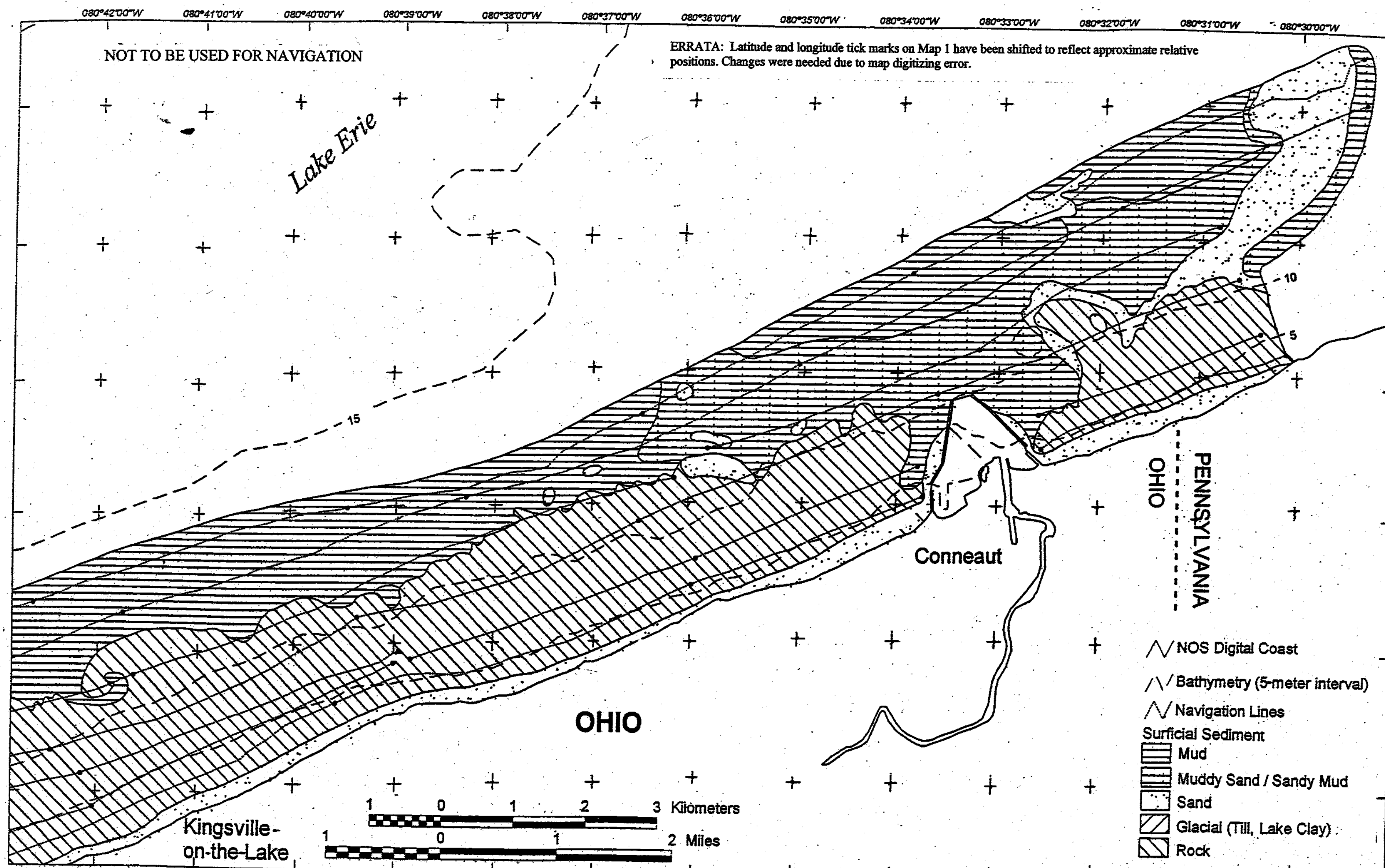
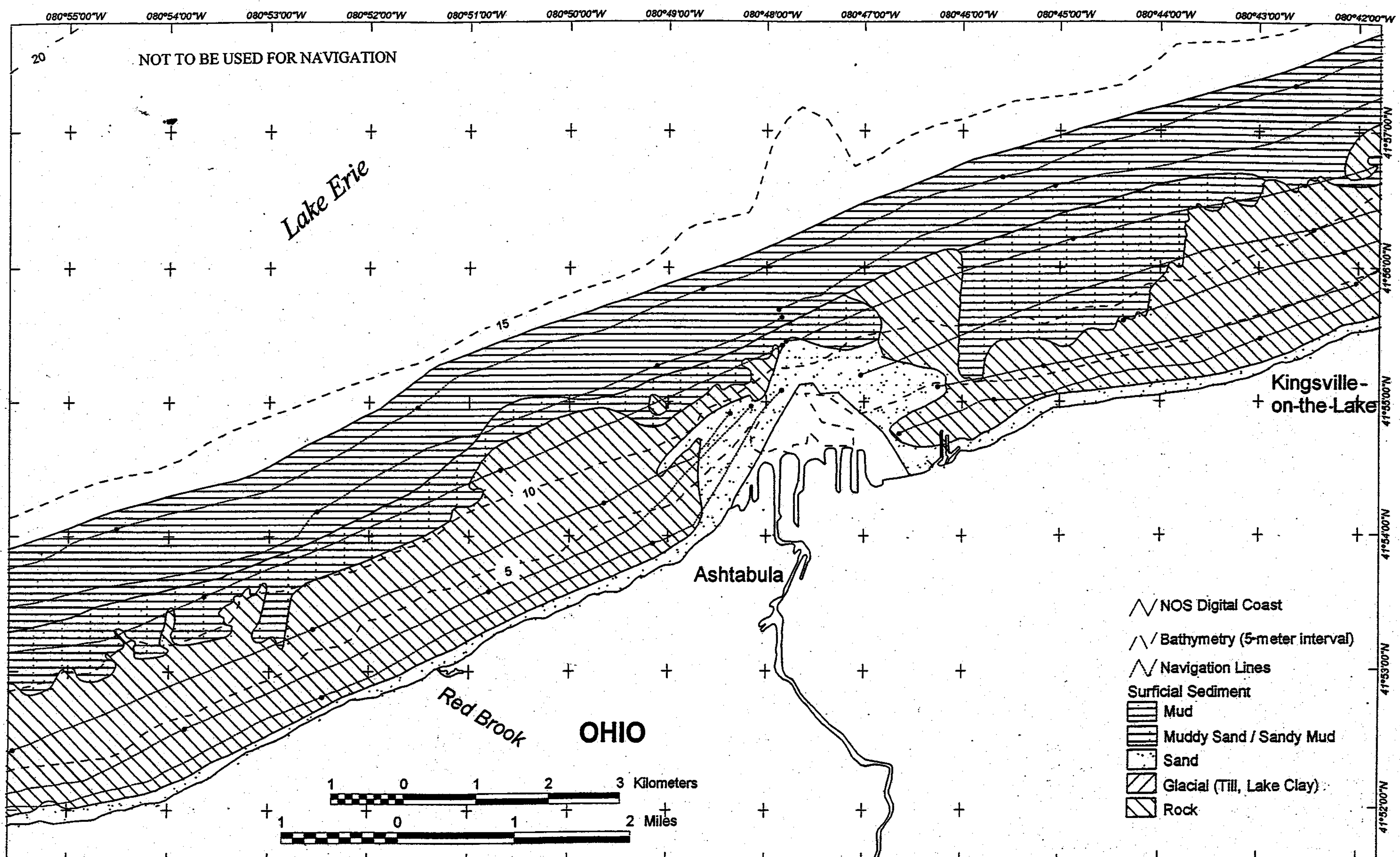


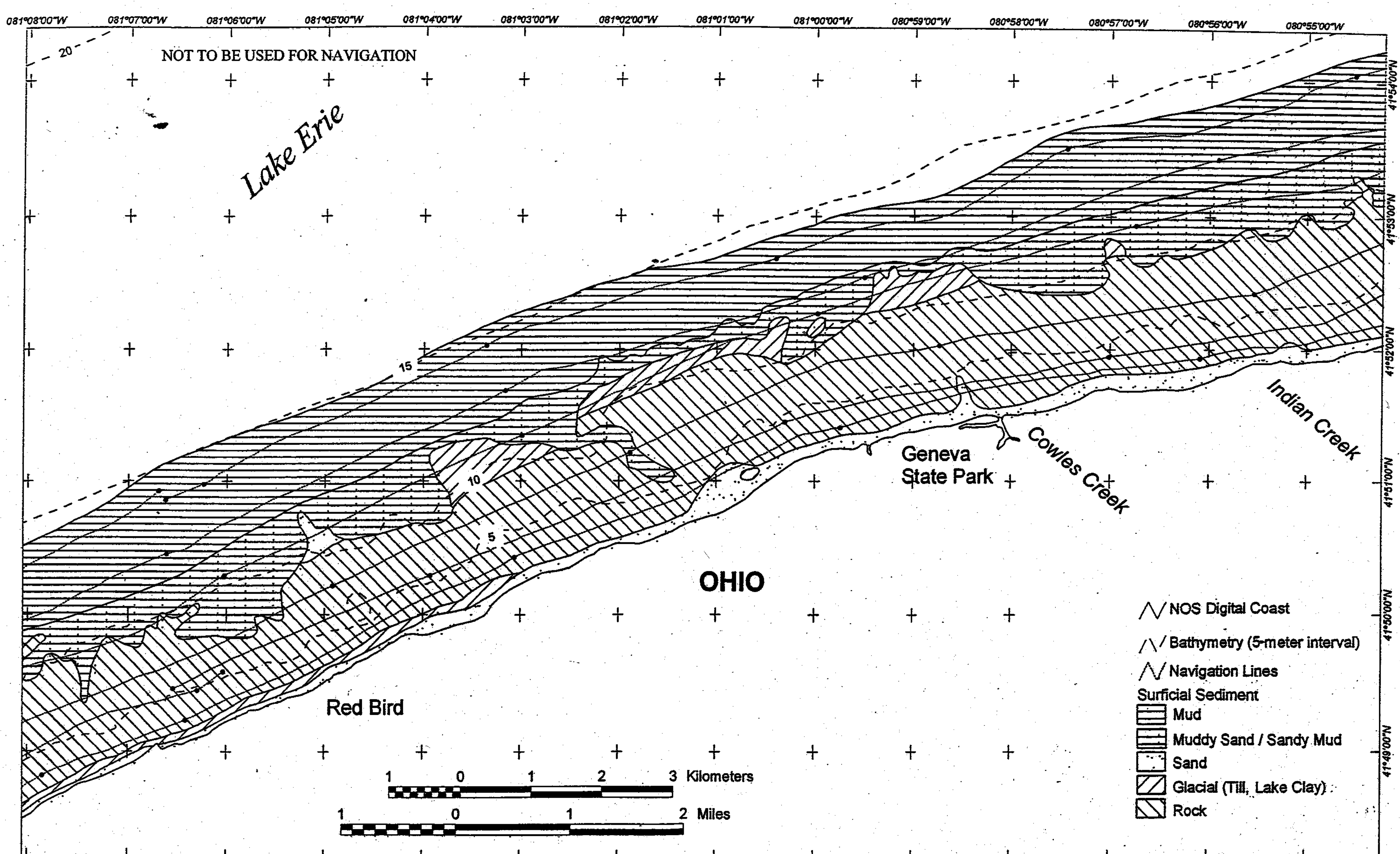
Fig. 7. Long-term recession rates (nominally 1876-1973) of the top of the bluff. The profile numbers and bluff recession rates are from preliminary designations of Coastal Hazard Zone Mapping being carried out by the Ohio Geological Survey. A. Modified from Mackey and Guy, 1994. B. Mackey and Guy file data. Missing transect numbers between A and B are within Sandusky Bay.



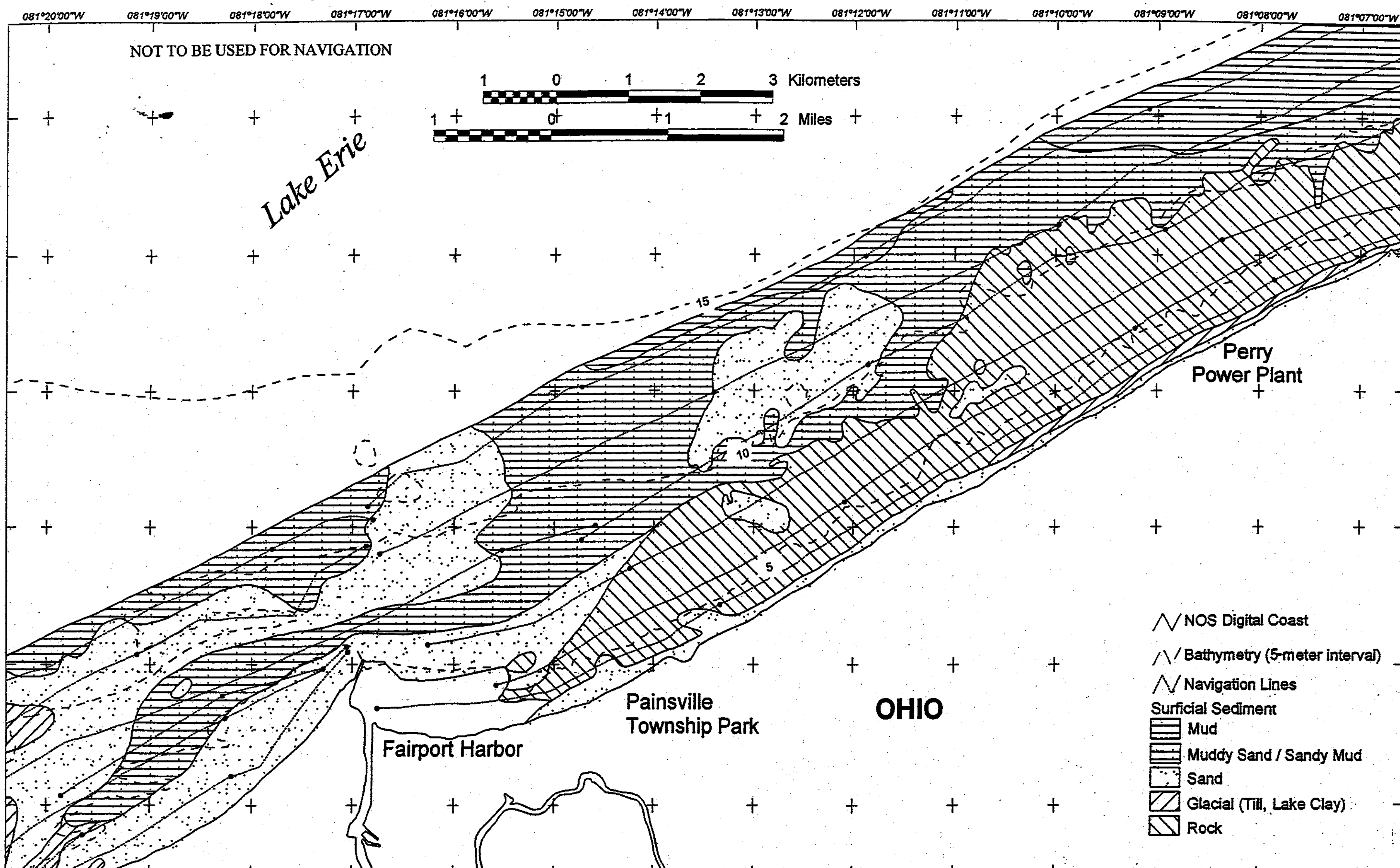
Map 1. Ohio-Pennsylvania state line to Kingsville-on-the-Lake



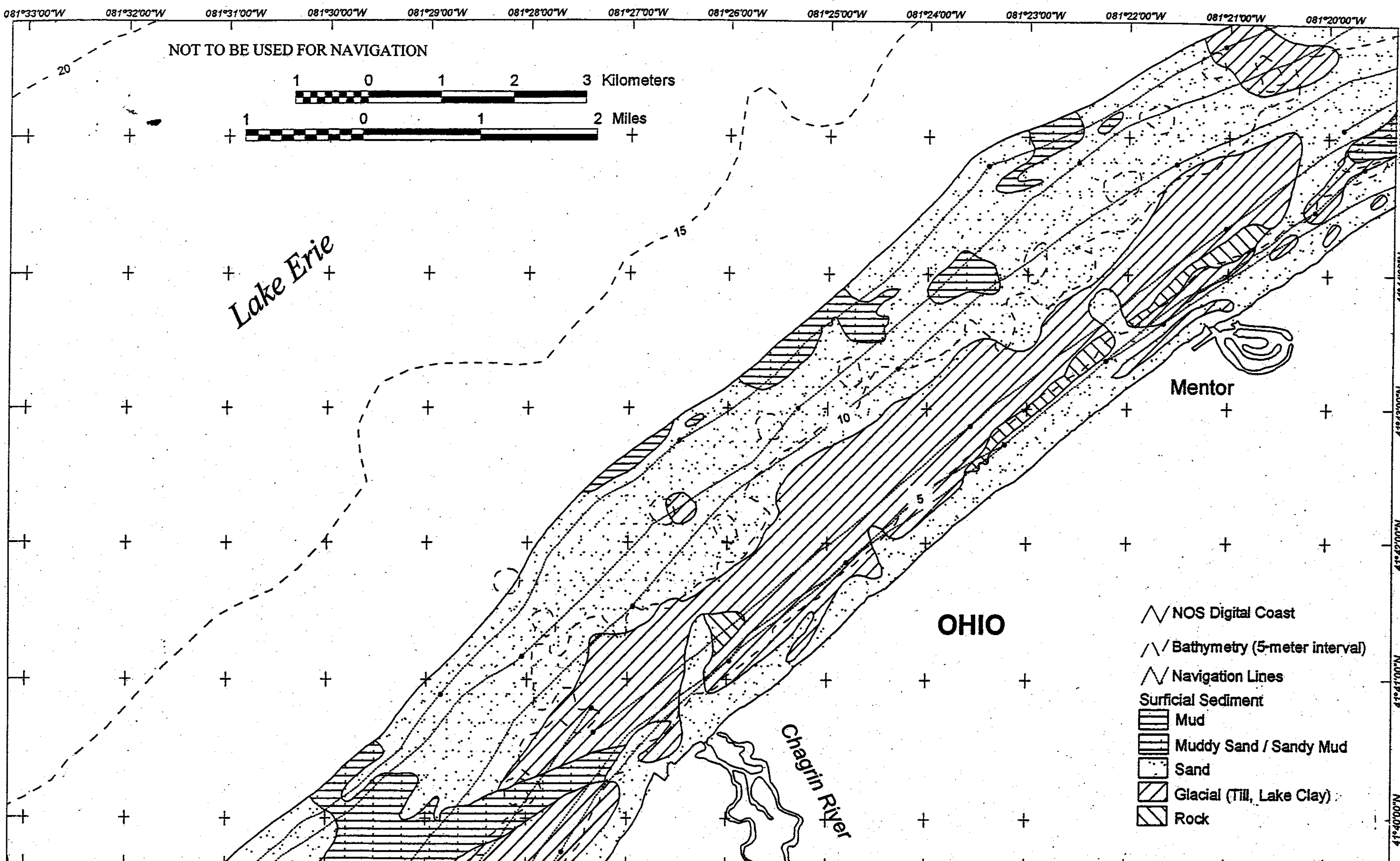
Map 2. Kingsville-on-the-Lake to east of Indian Creek



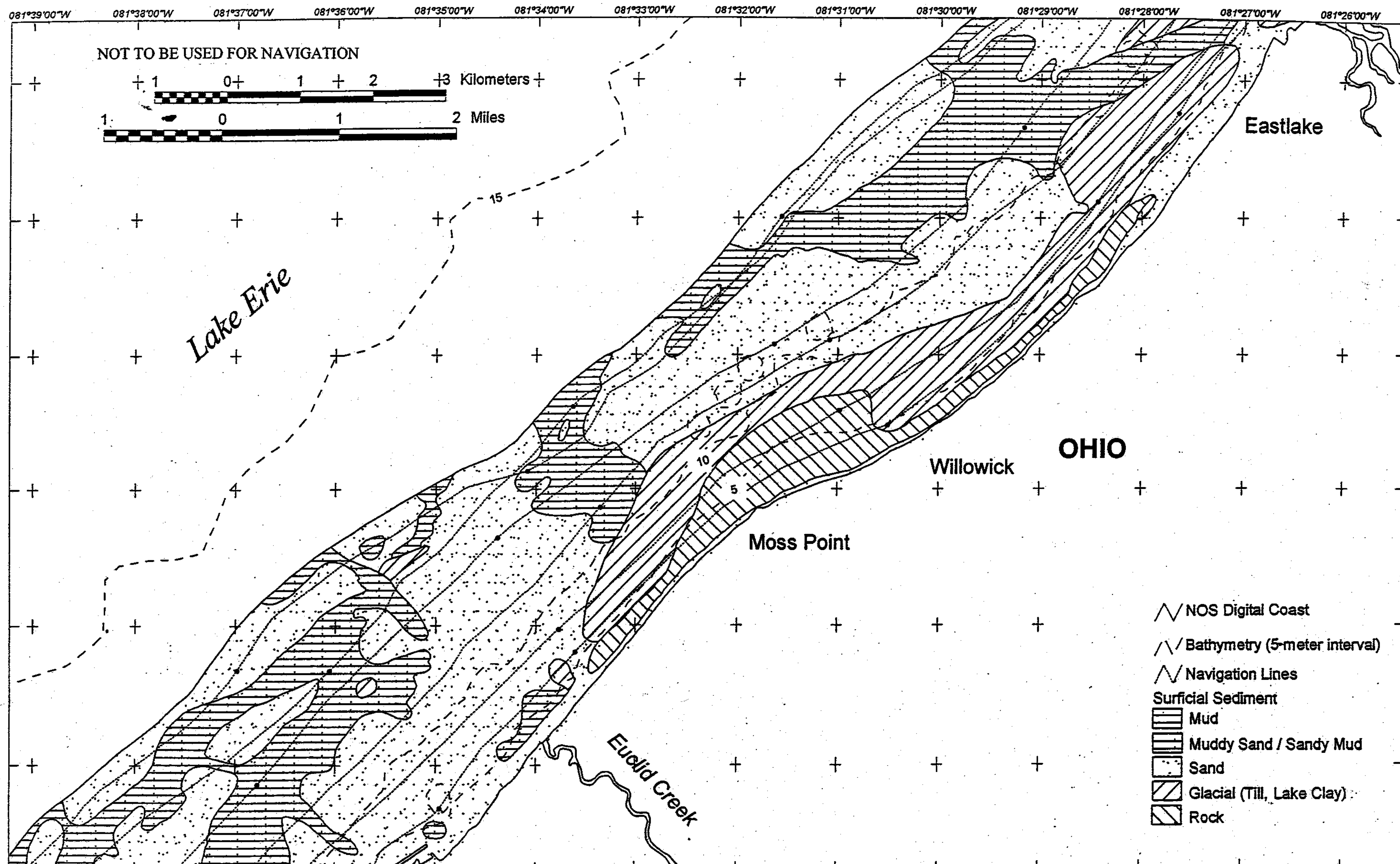
Map 3. Indian Creek to east of Perry Power Plant



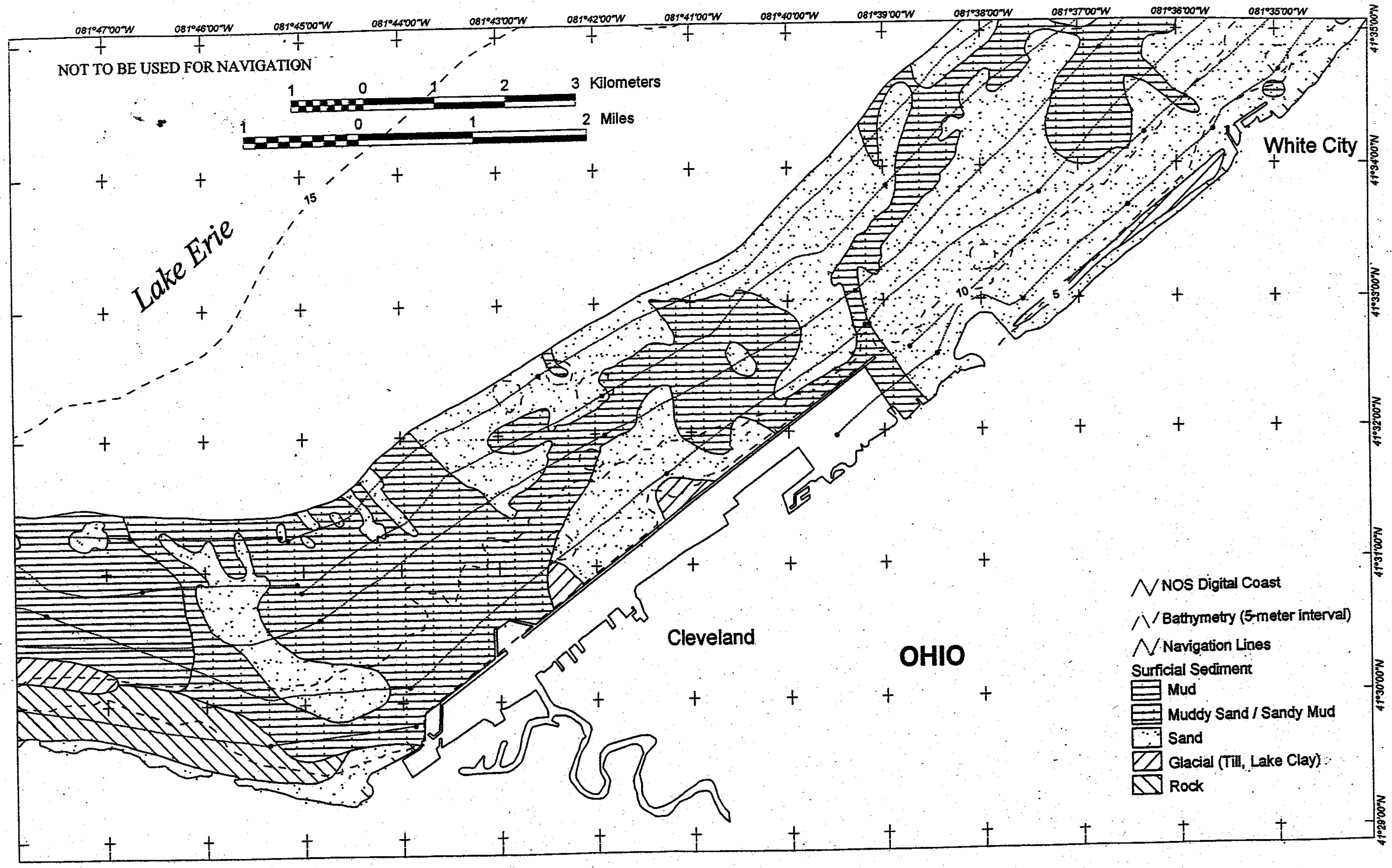
Map 4. Perry Power Plant to east of Mentor



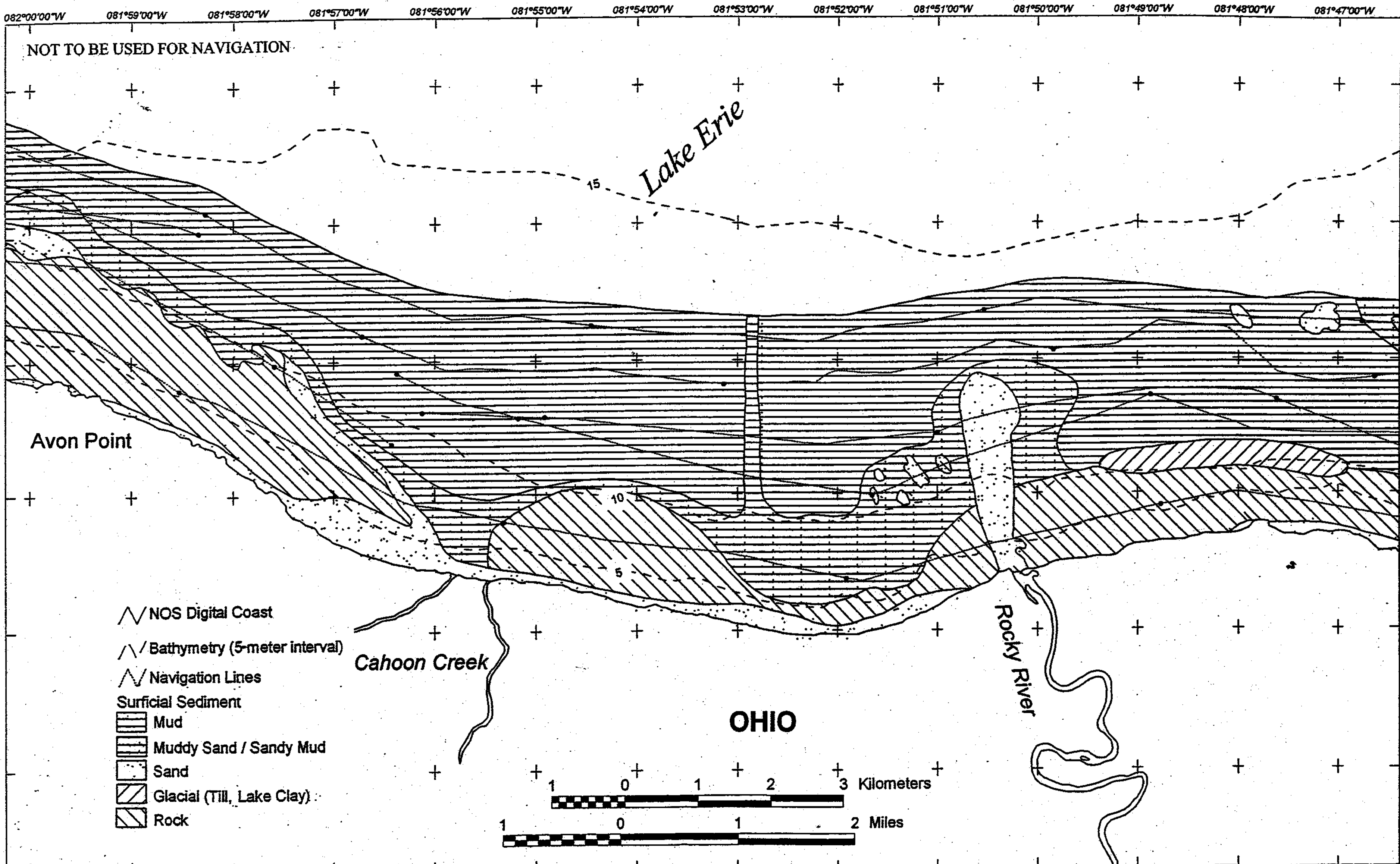
Map 5. Mentor Harbor to east of Eastlake



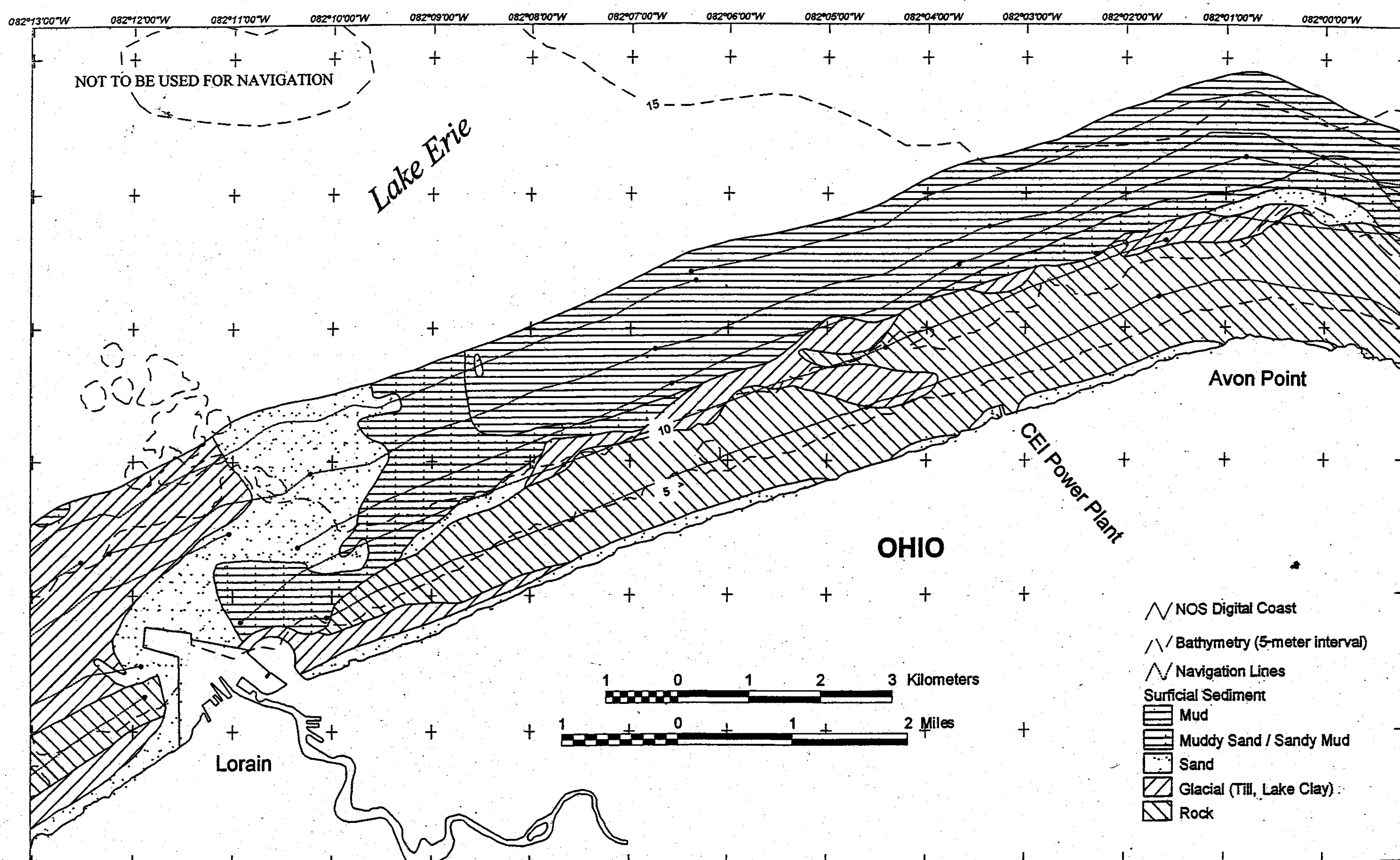
Map 6. Eastlake to east of White City



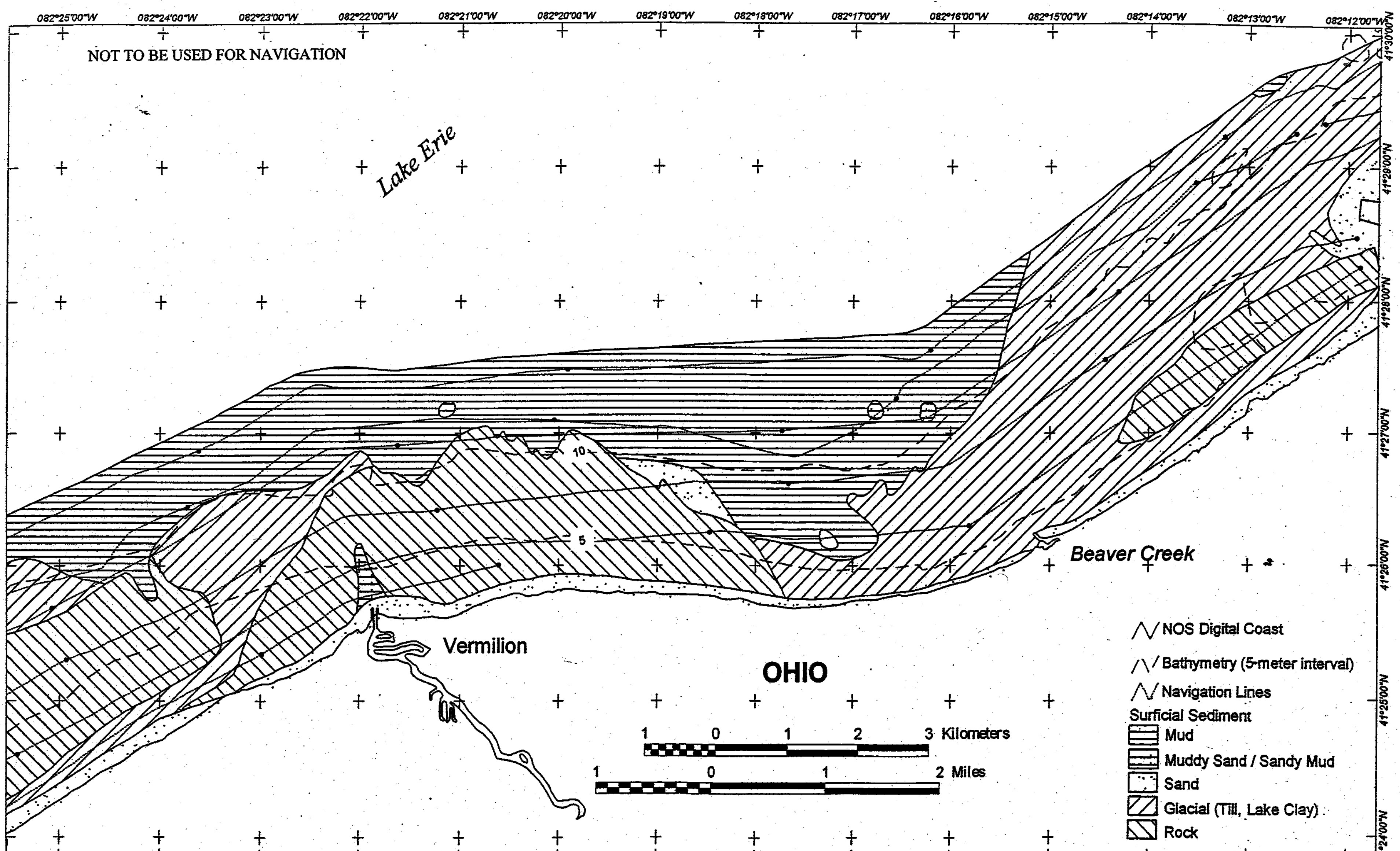
Map 7. White City to east of Rocky River



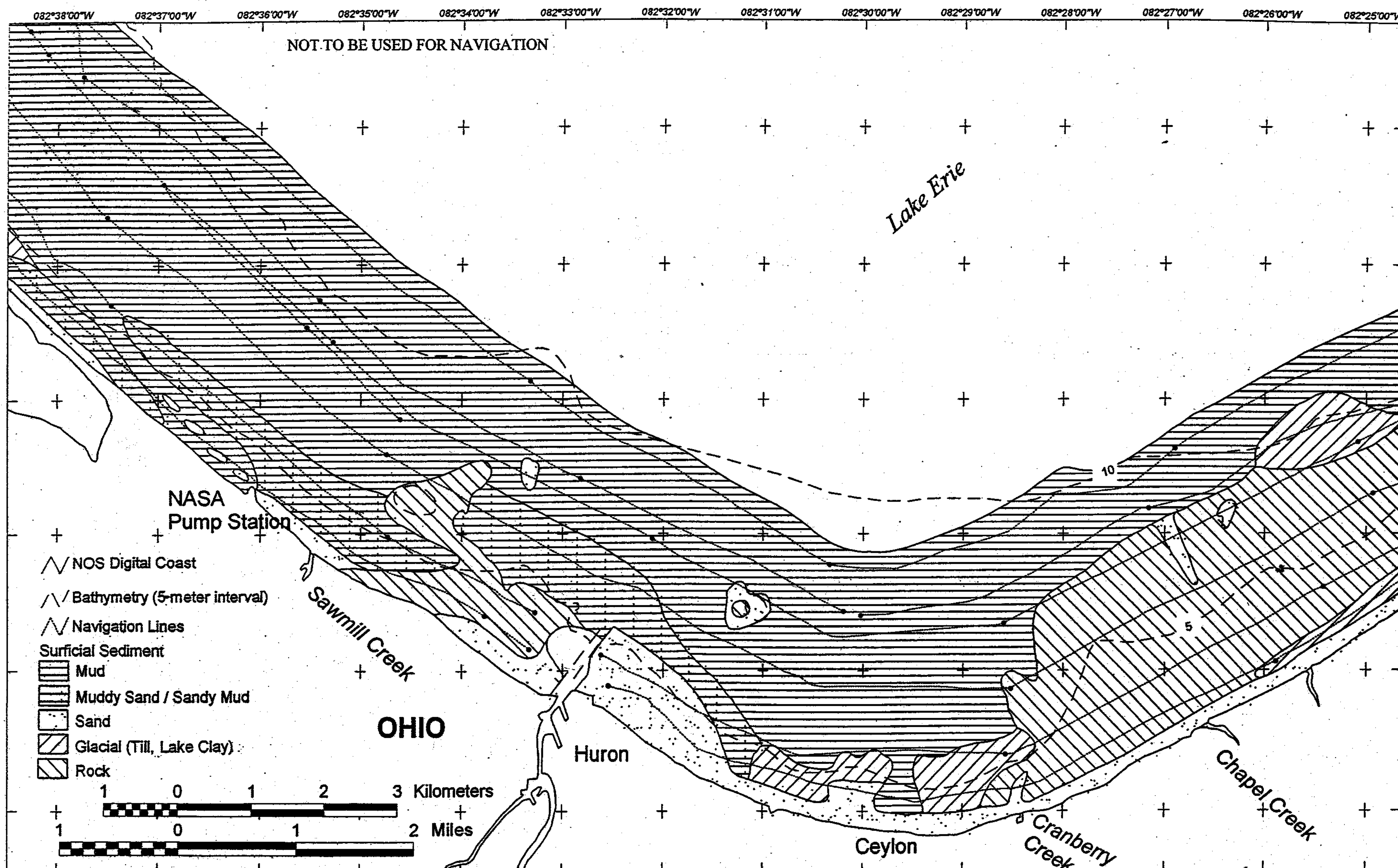
Map 8. East of Rocky River to Avon Point



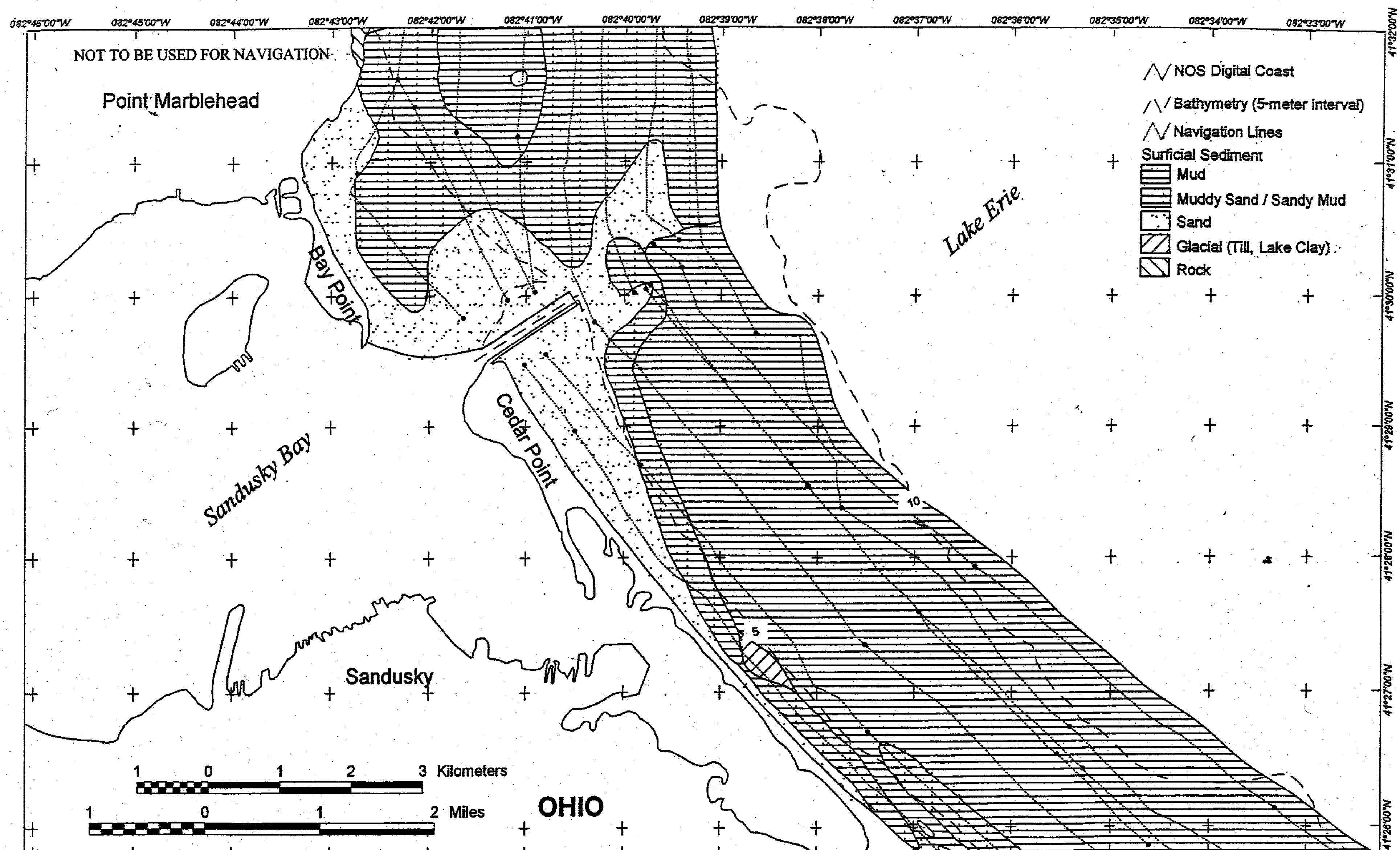
Map 9. Avon Point to Lorain



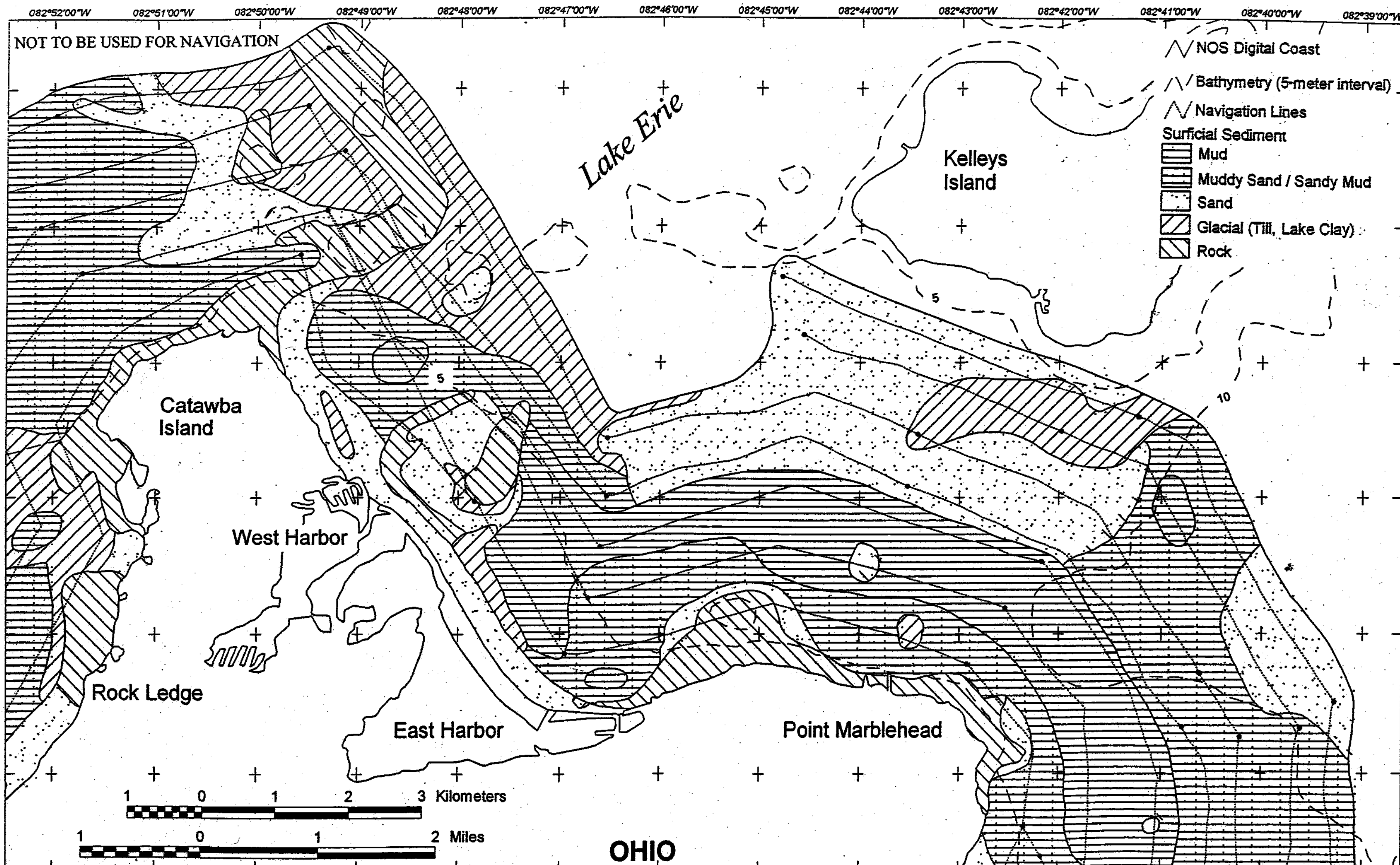
Map 10. West of Lorain to east of Chapel Creek



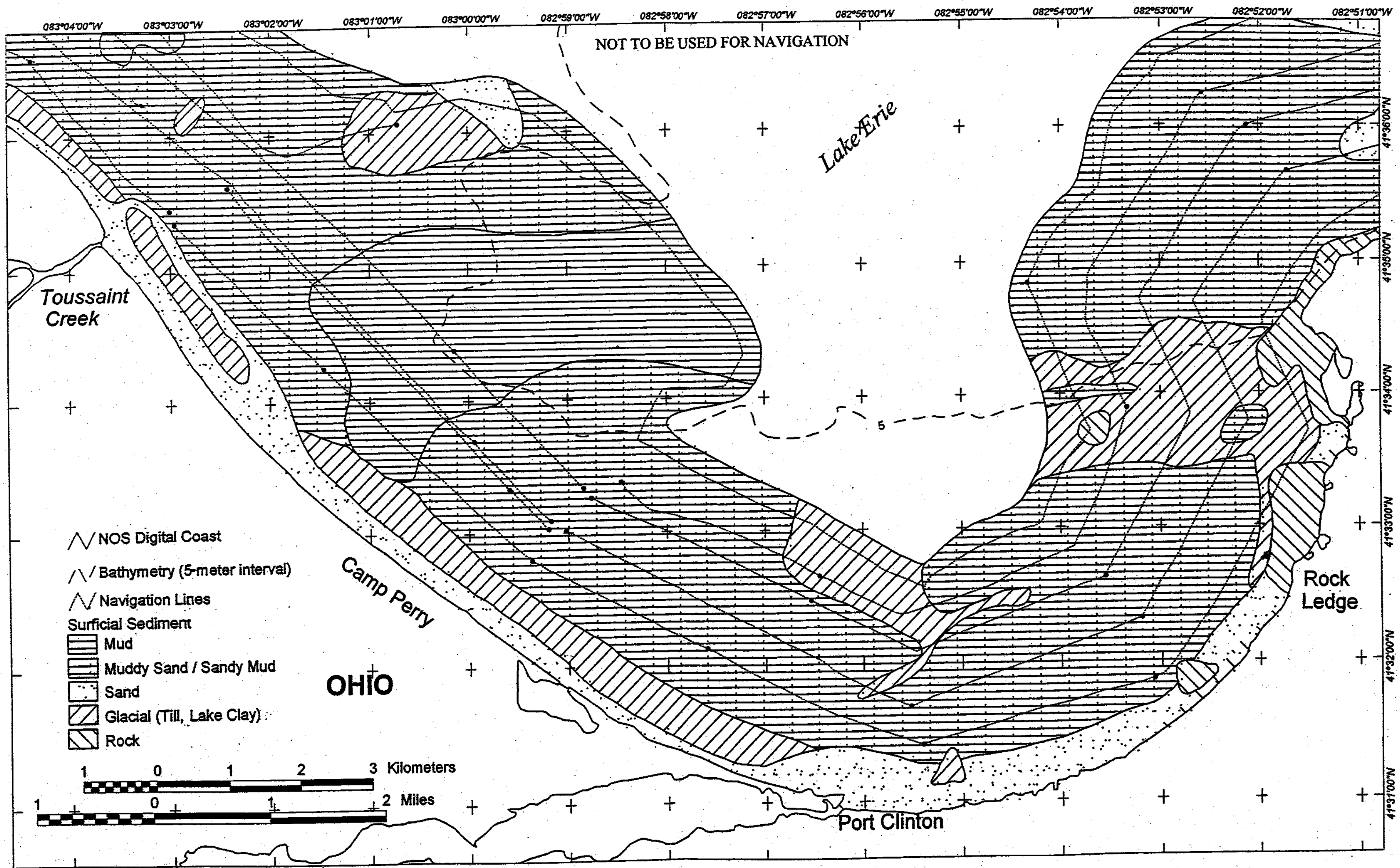
Map 11. Chapel Creek to east of Sandusky



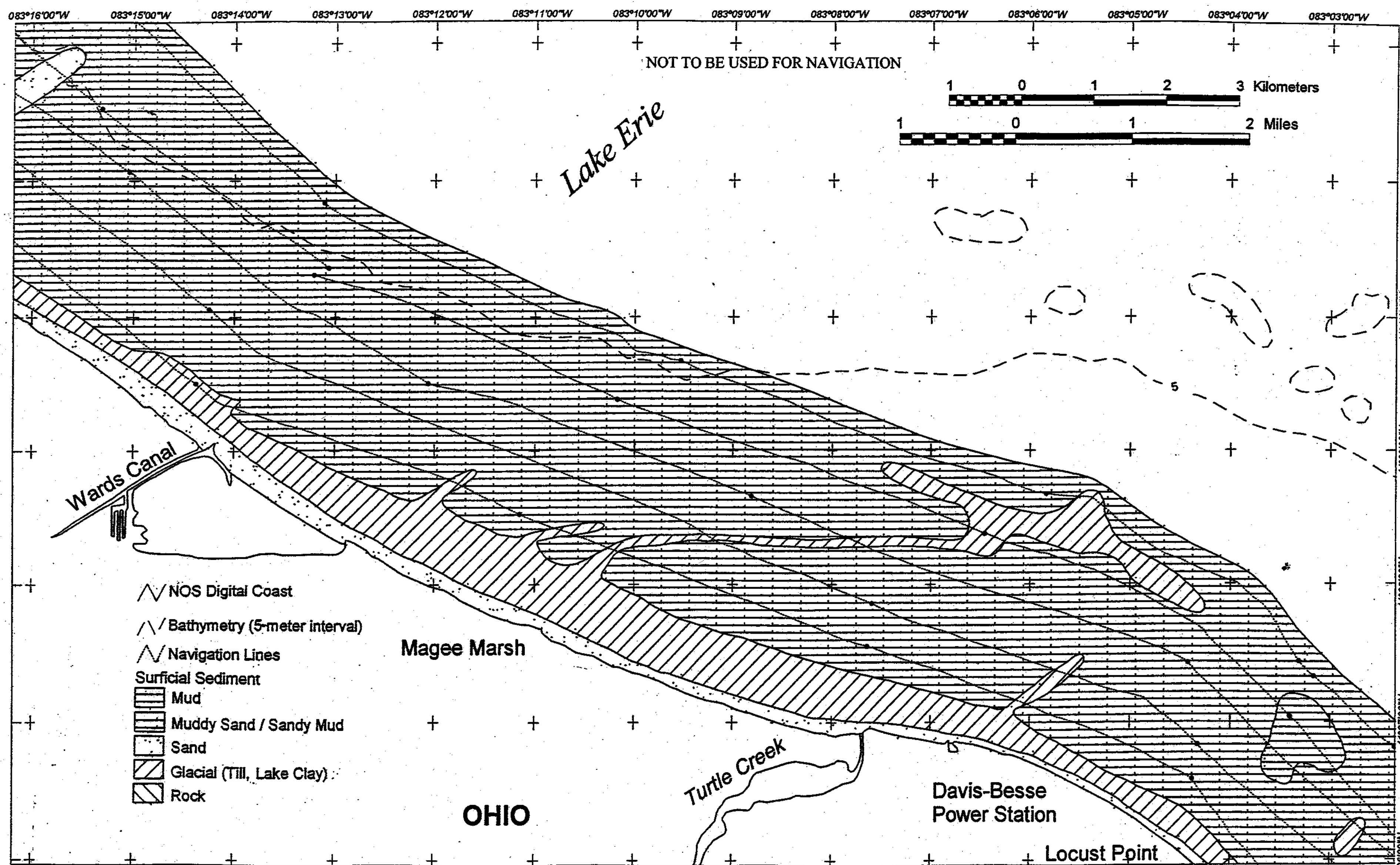
Map 12. Sandusky to Point Marblehead



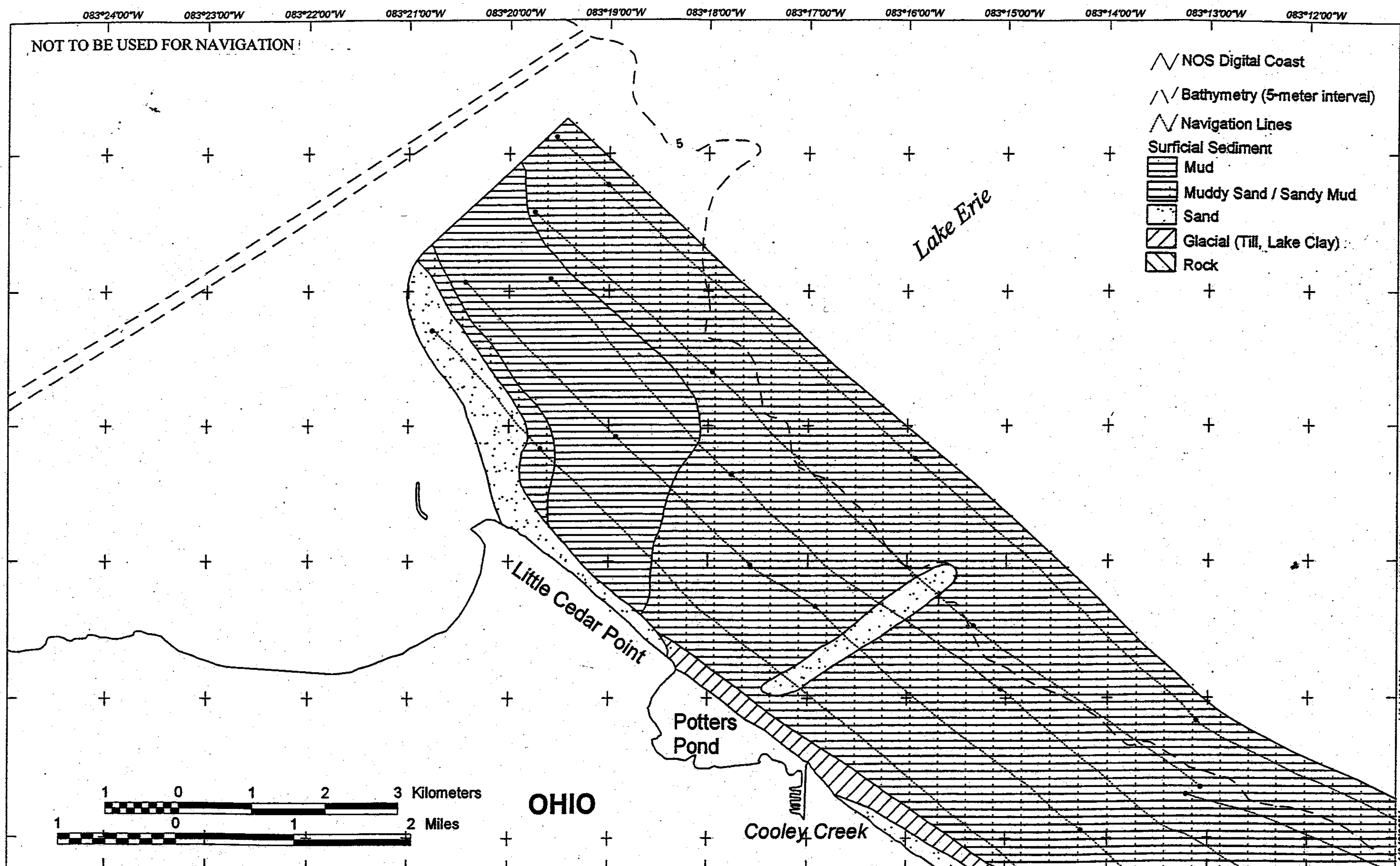
Map 13. Point Marblehead to Rock Ledge



Map 14. Rock Ledge to Toussaint Creek



Map 15. Locust Point to west of Wards Canal



Map 16. Cooley Creek to Little Cedar Point